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AIR QUALITY SURVEY OF INHALABLE PARTICULATES IN THE TOWN OF CANMORE

March 1 to May 10, 1994

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ENVIRONMENTAL PROTECTION

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AIR QUALITY SURVEY OF
INHALABLE PARTICULATES
IN THE TOWN OF CANMORE

March 1 to May 10, 1994

Prepared by:

Air Issues and Monitoring Branch
Alberta Environmental Protection

February 1995

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SUMMARY

Alberta Environmental Protection conducted an inhalable particulate monitoring survey in the Town of Canmore in March, April and May, 1994. The survey was the second component of an air quality study undertaken in the Bow Corridor. The first component of this study is detailed in the report entitled *"Mobile Monitoring Survey of the Bow Corridor - March 2 and 12, 1994"*.

The inhalable particulate component of the air quality study was designed to address local air quality issues including: smoke from local sources; automobile emissions; and haze and dust from industrial sources in Exshaw. These issues were identified by the Environmental Advisory Committee of the Canmore Town Council. The Environmental Advisory Committee was also involved in the design of the air quality study.

Inhalable particulates (<10 microns in diameter) were monitored for 13 consecutive days from March 1 to 13 for the purpose of establishing a baseline reference for the Canmore area. Samples collected on these days are referred to as *baseline* samples. Between March 22 and May 10, additional particulate samples were collected when wind direction had a southeast component. Samples collected on these days represent times when there was a greater potential for transport of pollutants from the Exshaw area to the Town of Canmore. These samples are referred to as *test* samples.

Dichotomous and selective size inlet (SSI) samplers were set up on the west edge of downtown Canmore. Inhalable particles were measured by the dichotomous sampler in two size fractions: fine (< 2.5 microns) and coarse (2.5 to 10 microns). The SSI sampler collected only particles less than 10 microns in diameter. Chemical analysis was performed on dichotomous samples to obtain: (a) inhalable particulate loadings; and (b) anion and cation concentrations. Additional analysis was conducted on SSI samples to quantify concentrations of polycyclic aromatic hydrocarbons (PAHs). Wind speed and direction were also monitored at this location.

Wind directions with a southeast component were observed 3% of the time in *baseline* samples compared to 24% of the time in *test* samples. Wind speeds were also lower in *test* samples with median wind speeds in *test* and *baseline* samples of 4.2 and 6.6 km/h, respectively. The majority of winds in both sample sets were from the west to northwest, conforming to the orientation of the Bow River Valley (84% in *baseline* samples and 49% in *test* samples).

The following key points are evident from this study:

- **Fine particulate loadings (<2.5 microns) in Canmore were not significantly different than those measured in downtown Calgary for the same time period.** Median fine particulate loadings in Canmore and downtown Calgary were 9.1 and 9.0 ug/m^3 (micrograms per cubic meter), respectively. Concentrations of most ions in the fine fraction were lower in Canmore samples than Calgary downtown samples. However, sulphate, nitrate and calcium values were higher in Canmore samples.

- **The median fine particulate loading (<2.5 microns) in *test* samples was lower than the median value for *baseline* samples.** Median fine particulate loadings in *baseline* and *test* samples were 11.0 and 7.3 ug/m^3, respectively. Concentrations of ammonium, potassium, sulphate and nitrate in the fine fraction were higher in *test* samples than *baseline* samples.

- **Coarse particulate loadings (2.5 to 10 microns) in Canmore samples were significantly lower than those measured in downtown Calgary.** The median coarse particulate loading in Canmore samples was about one-third of the median value recorded in downtown Calgary. Ammonium was the only ion in the coarse fraction that recorded a higher median concentration in Canmore samples.

- **The median coarse particulate loading (2.5 to 10 microns) was over three times higher in *test* samples than *baseline* samples.** Median concentrations in *baseline* and *test* samples were 5.3 and 17.0 ug/m^3, respectively. Concentrations of most ions were also higher in *test* samples than *baseline* samples for the coarse particulate fraction. Median concentrations of coarse calcium, sulphate, nitrate, ammonium, sodium, chloride, magnesium and potassium were at least twice as high in *test* samples. The median calcium concentration in the coarse fraction was over 13 times higher in *test* samples than *baseline* samples.

- **With the exception fluoranthene and phenanthrene, PAH concentrations in Canmore SSI samples were lower than those measured in Calgary downtown high volume samples.** Concentrations of most PAHs were either close to the same in *baseline* and *test* samples or higher in *baseline* samples (benzo (a) pyrene, benzo (k) fluoranthene, pyrene, phananthrene, fluorene and acenaphthene). The median fluoranthene concentration was 2.7 times higher in *test* samples than *baseline* samples. Naphthalene and anthracene concentrations were also higher in *test* samples.

Sources of many ions in the Canmore area may be related to industrial activities in Exshaw such as cement manufacturing or magnesium oxide production. This is especially true for fine particulates (< 2.5 microns) such as sulphate, nitrate and ammonium which may be emitted by combustion processes associated with these industries. Product preparation processes such as mining and transport of materials are likely major sources of some of the coarse particles (2.5 to 10 microns) observed at the Canmore monitoring station. In addition, natural wind-blown dust is also a likely primary source of particulates in the coarse fraction (calcium, sulphate, nitrate, ammonium, sodium, chloride, magnesium and potassium).

Most PAHs measured at the Canmore station appear to originate from sources to the northwest or sources in the Canmore area. Some PAHs, such as fluoranthene, anthracene and naphthalene, may also be transported from industrial facilities in the Exshaw area. The major sources of these PAHs measured in the Canmore area are diesel and gas exhaust emissions, and smoke from recreational wood burning.

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We would also like to acknowledge the Alberta Environmental Centre in Vegreville, Alberta and the Environmental Technology Centre in Ottawa, Ontario for chemical analysis of the samples. The Alberta Environmental Centre conducted chemical analysis on the SSI and dichotomous samples from Canmore and high-volume samples from Calgary. The Environmental Technology Centre in Ottawa, Ontario conducted chemical analysis on the Calgary dichotomous samples.

ABBREVIATIONS

PAH - polycyclic aromatic hydrocarbon

B(a)P - benzo (a) pyrene

B(k)F - benzo (k) fluoranthene

SSI - selective size inlet

NAPS - National Air Pollution Surveillance system

NIST - National Institute of Standards and Technology

um - microns

ug/m^3 - micrograms per cubic meter

ng/m^3 - nanogram per cubic meter

km/h - kilometers per hour

AIR QUALITY SURVEY OF INHALABLE PARTICULATES IN THE TOWN OF CANMORE MARCH 1 TO MAY 10, 1994

1. INTRODUCTION

Alberta Environmental Protection conducted an air quality monitoring study in the Bow Corridor in response to a request from the Environmental Advisory Committee of the Canmore Town Council. The air quality study consisted of two components:

(1) a mobile air quality monitoring survey of the Bow Corridor; and
(2) a study of inhalable particulates in the Town of Canmore.

The following report details the results from the inhalable particulate survey undertaken in Canmore. The results of the mobile monitoring survey are discussed in the report entitled *"Mobile Monitoring Survey of the Bow Corridor: March 2 and 12, 1994"*. This report is available from Alberta Environmental Protection.

The air quality study was initiated to address local air quality issues. These issues, as identified by the Environmental Advisory Committee, are:

(1) smoke from local sources, including fire places and slash burning;
(2) automobile emissions from the Trans-Canada Highway;
(3) haze and dust from the industries in Exshaw;
(4) the apparent rise in asthma cases in school children; and
(5) the characteristics and behaviour of the air flow in the valley.

The mobile monitoring and inhalable particulate surveys addressed the first three of these issues. The information obtained from the air quality study may be used, by the appropriate experts, to further assess air quality as it relates to human health in the region.

2. DESCRIPTION OF THE MONITORING SURVEY

Inhalable particulates were monitored by two samplers in the Town of Canmore. A selective size inlet (SSI) sampler and dichotomous sampler were installed on the roof of the former Alberta Liquor Control Board building on 8th Avenue and 8th Street in Canmore. Both samplers have the capability to monitor inhalable particulate matter (< 10 um (microns) in diameter). The dichotomous sampler will also monitor particles less than 2.5 um in diameter. Both monitoring techniques were used so that sufficient sample would be available to conduct chemical analysis for species contained in the sample.

The study was designed to collect 13 samples on a daily basis from March 1 to 13. It was assumed that this 13 day period would adequately represent a baseline for the survey. After

March 13, samples were collected when wind conditions were optimal for transport of emissions from the industrial facilities in Exshaw area to Canmore. The criteria for sampling on these days were wind directions with a southeast component.

In this report, samples that were collected from March 1 to 13 will be referred to as the ***baseline samples***. Samples collected after March 13 will be referred to as ***test samples.***

Chemical analysis on dichotomous samples was conducted to quantify the following:

- total particulate weight; and
- concentrations of anions and cations (chloride, nitrate, sulphate, sodium, ammonium, potassium, magnesium and calcium).

In additional chemical analysis was conducted on SSI samples to obtain:

- concentrations of polycyclic aromatic hydrocarbons (acenaphthene, anthracene, naphthalene, fluorene, phenanthrene, fluoranthene, pyrene, benzo (k) fluorene and benzo (a) pyrene).

Table 2.1 shows the analytical methods used in chemical analysis of particulate samples. These analysis procedures are detailed in the "Methods Manual for Chemical Analysis of Atmospheric Pollutants: 1993" produced by the Alberta Environmental Centre (1993).

Table 2.1 Analytical methods used in chemical analysis of particulate samples.

Parameter	Analytical Technique	Method Number[1]
particulate loading	gravimetric	25050
sulphate	ion chromatography	26060
nitrate	ion chromatography	24040
anions and cations (chloride, sodium, ammonium, potassium, magnesium and calcium)	ion chromatography	52626
polycyclic aromatic hydrocarbons	high performance liquid chromatography	25555
benzo (a) pyrene	high performance liquid chromatography/fluorescence	21516

[1] refers to method number in methods manual

2.1 SITE DESCRIPTION

The Town of Canmore is located in the base of the Bow River Valley approximately 15 km west-northwest of Exshaw and 25 km southeast of Banff. The elevation of the town is approximately 4300 feet above sea level. The Bow Valley runs northwest-southeast through Banff and Canmore and curves to a west-east orientation towards Exshaw. Because of the defined (mountainous) topography in the region, it was necessary to monitor wind direction and speed in Canmore at the particulate monitoring location.

The particulate monitoring site was located on the west edge of downtown Canmore. This location was approximately 800 m from Highway #1A and 1000 m from the Trans-Canada Highway. Figure 2.1 shows the monitoring site location and the local topography of the region.

2.2 PARTICULATE SAMPLING INSTRUMENTATION

2.2.1 Selective Size Inlet Sampler

The selective size inlet (SSI) is a modification of the high volume sampler to collect only particles less than 10 microns in diameter. Particles less than 10 um are considered small enough to be inhaled into the respiratory system. The SSI sampler consists of a vacuum pump, flow controller and filter housed in a shelter. The suspended particulate matter in the atmosphere is collected by drawing a known volume of air through a pre-weighed filter for a 24-hour period. Suspended particles with a diameter less than 10 um, Stokes equivalent, will be collected on the filter (Environment Canada, 1973). The filter is then reweighed to determine the mass of the particles collected. The total particulate concentration for the 24-hour period may then be calculated.

The SSI sampler ran alternately with two types of filters. A quartz filter was used to minimize interferences in the analysis of heavy metals. Analysis for heavy metals on the quartz filters was not completed on all samples due to laboratory instrument malfunction. A teflon coated glass fiber filter was used for the remaining samples. The interference for anions and cations on the quartz and teflon filters was tested using laboratory blanks. This interference was determined to be minimal for all ions presented in this report. Therefore, in the presentation of analytical results, SSI samples collected by quartz and teflon filters are not distinguished.

The selective size inlet sampler was calibrated at the beginning and end of the monitoring program. Two calibrations were conducted in the field during the monitoring program. The calibrations were done with the Kurtz NIST (National Institute of Standards and Technology) traceable mass flow calibrator.

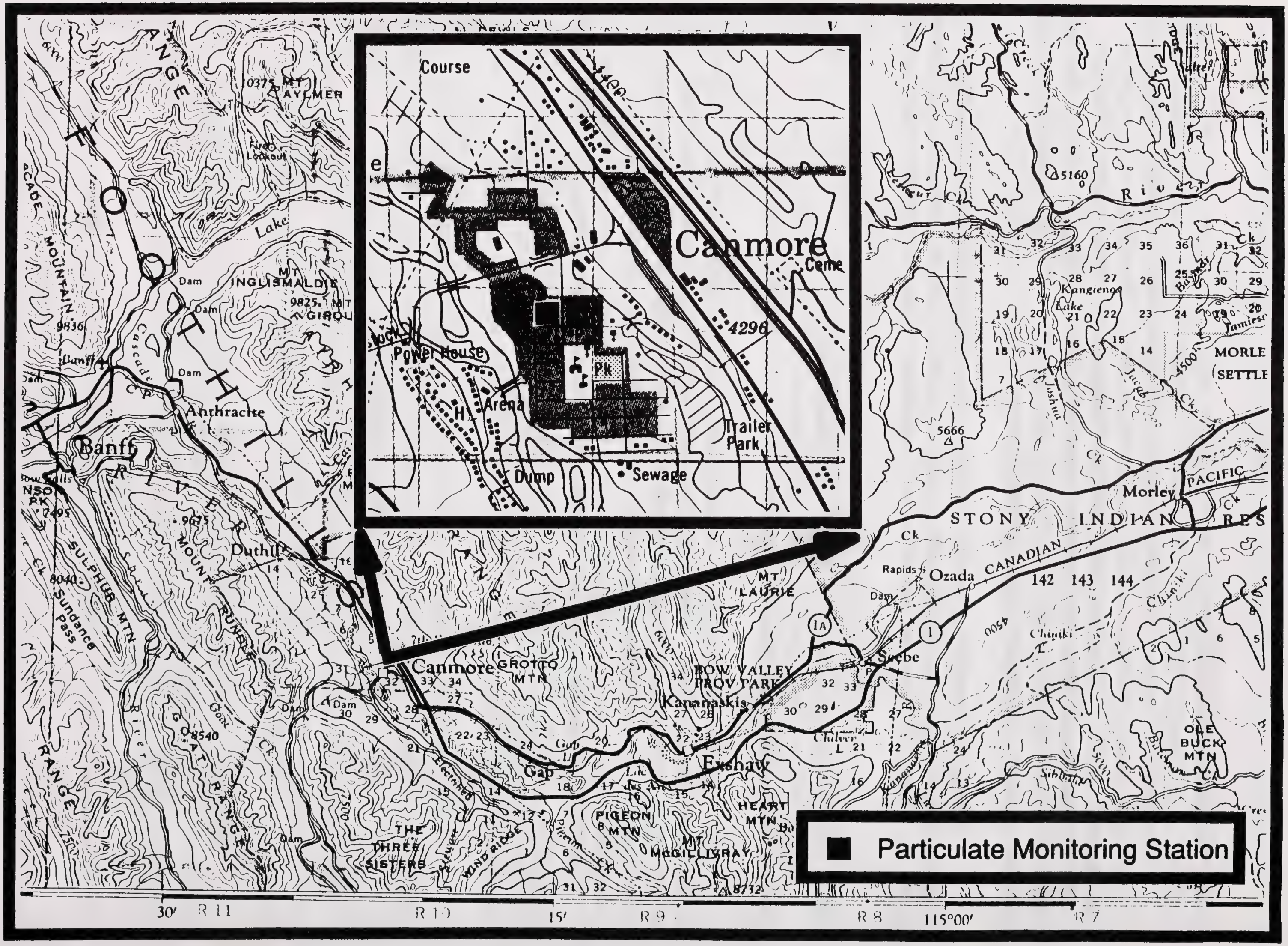


Figure 2.1 Location of particulate monitoring station.

2.2.2 Dichotomous Sampler

The dichotomous sampler is a derivative of the high volume sampler. The sampler aerodynamically separates the particles into two size fractions; fine (< 2.5 um) and coarse (2.5 to 10 um). Fine and coarse particles are collected by drawing a known volume of air through two individual pre-weighed filters for a 24-hour period. The total particulate concentration in the two size ranges may then be calculated for the 24-hour period. Particulates were collected with a teflon filter supported by a 37 mm polyolefin ring.

The dichotomous sampler was calibrated with the Gilibrator mass flow traceable to NIST. Calibrations were conducted in the laboratory prior to field operations and again at the end of the monitoring program. Two additional field calibrations were also conducted during the survey.

2.2.3 Wind Instrument

Wind speed and direction were measured by a Windflow 540 wind speed anemometer and wind direction vane. The threshold wind speed for this instrumentation is about 2 km/h. Wind data is recorded once every five seconds by the on-site data acquisition system. The data acquisition system then calculates five-minute and one-hour averages for wind speed and direction. The wind instrument was located at a height of 10 m on top of the former ALCB building in Canmore.

3. RESULTS OF THE MONITORING SURVEY

Inhalable particulate samples were monitored in March, April and May, 1994 in Canmore. Particulate samples were collected by a dichotomous and selective size inlet (SSI) sampler. Wind speed and direction were also monitored in Canmore during the survey.

Chemical analysis was conducted on dichotomous samples from Canmore to determine total particulate loading as well as anion and cation concentrations. Polycyclic aromatic hydrocarbon (PAH) concentrations were obtained from SSI samples. Anions and cations analyzed were sulphate, nitrate, chloride, calcium, ammonium, sodium, magnesium and potassium. PAHs analyzed were benzo (a) pyrene, benzo (k) fluoranthene, pyrene, fluoranthene, phenanthrene, fluorene, naphthalene, anthracene and acenaphthene.

For the purpose of determining a reference for data collected in Canmore, chemical analysis for particulate loadings and ion concentrations was performed on dichotomous samples collected from March 3 to April 14, 1994 at the Calgary downtown monitoring station. In addition, analysis for PAH concentrations was conducted on high volume samples from the Calgary downtown station (March 3 to April 8, 1994). A rigorous statistical comparison of PAH concentrations from Canmore SSI data and Calgary downtown high volume data is not scientifically valid because the SSI sampler collects only particles with a diameter of less than 10 microns while the high volume sampler collects all suspended particles including those with a diameter greater than 10 microns. Dichotomous and high volume samples at the Calgary downtown station (as well as other permanent Alberta Environmental Protection high volume stations) are collected every sixth day in accordance with the National Air Pollution Surveillance (NAPS) system.

For the purpose of data analysis, particulate samples collected in Canmore were separated into two data sub-sets. These data sub-sets are referred to as *baseline* samples and *test* samples and are described as follows:

- *baseline* samples - samples collected from March 1 to 13 in order to determine a representative baseline for reference; and
- *test* samples - samples that were collected after March 13 when wind directions from the east-southeast, southeast or south-southeast were reported.

A total of 13 samples are contained in the *baseline* data subset. Four and seven samples are contained in the *test* data sub-set for the dichotomous and SSI samplers, respectively. The individual sample days are indicated in Table 3.1. The SSI sampler in Canmore was run with the same filter on March 29 and April 4. The analytical results for this sample were then simply averaged for the two days.

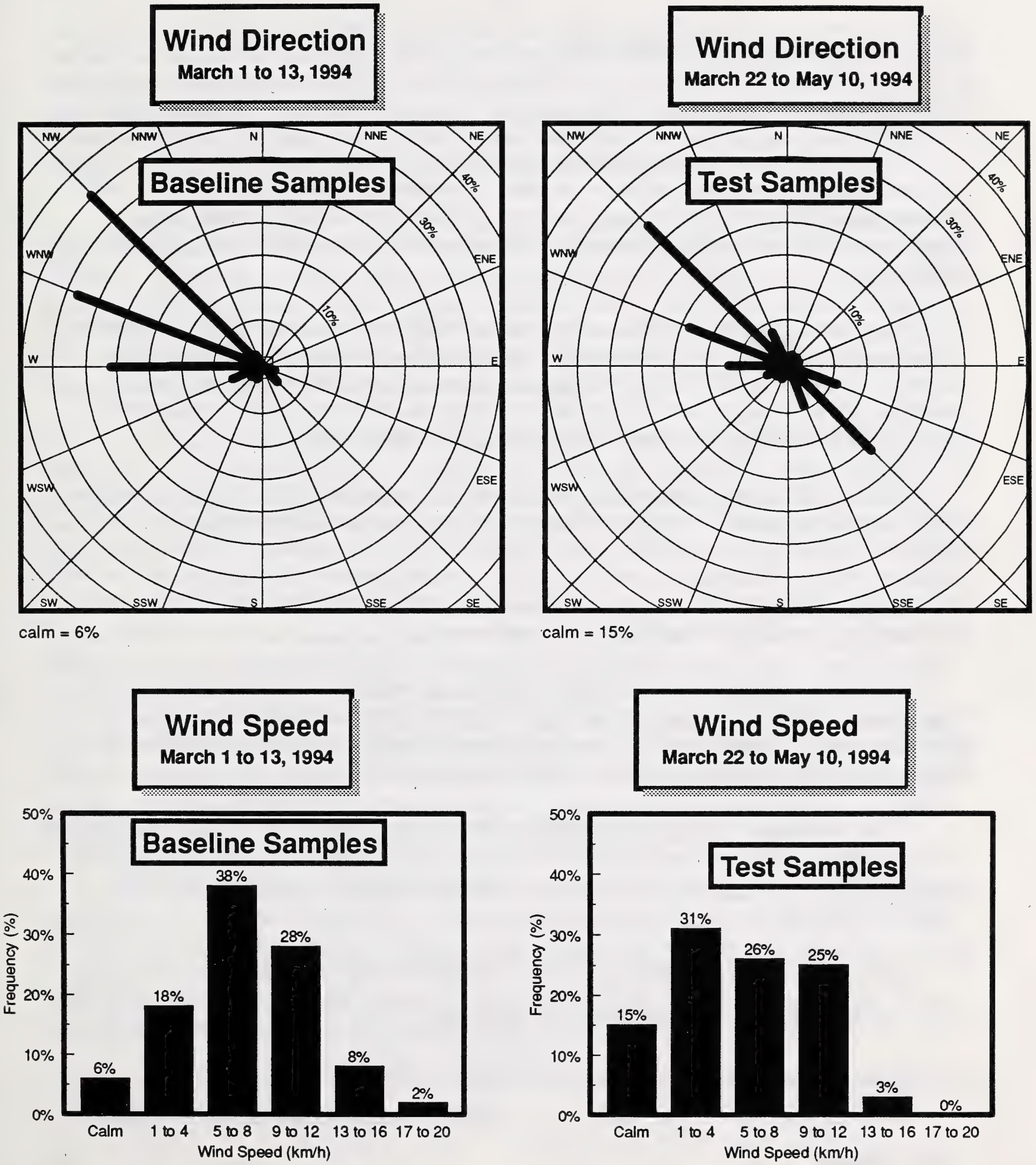
Table 3.1 Sample dates for Canmore and Calgary downtown particulate samples.

Canmore Dichotomous Sample Dates	Calgary Downtown Dichotomous Sample Dates	Canmore SSI Sample Dates	Calgary Downtown High Volume Sample Dates
March 1 to 13, inclusive	March 3	March 1 to 13, inclusive	March 3
April 20	March 9	March 22	March 9
April 21	March 15	March 29	March 15
April 27	March 21	April 4	March 21
May 10	March 27	April 20	March 27
	April 2	April 21	April 2
	April 8	April 27	April 8
	April 14	May 10	

3.1 WIND DATA

Wind direction and wind speed frequency distributions for *baseline* and *test* samples are presented in Figure 3.1. Wind directions were predominantly from the northwest, west-northwest and west on *baseline* sample days (84%). Winds from the northwest to west were also common on *test* sample days (49%). East-southeast, southeast and south-southeast winds were also frequent on *test* sample days (24%). These wind directions are consistent with the southwest-northeast orientation of the Bow River Valley in the Canmore area.

Wind speeds were substantially lower on *test* sample days than on *baseline* sample days. On *baseline* sample days, the highest frequency of wind speeds was in the 5 to 8 km/h range while wind speeds in the 1 to 4 km/h range were most frequent on test sample days. Calm winds (less than the instrument detection limit) occurred 6% of the time on *baseline* sample days as compared to 15% of the time on *test* sample days. Median wind speeds were 6.6 and 4.2 km/h, respectively, on *baseline* and *test* sample days.



Wind Direction March 1 to 13, 1994

Wind Direction March 22 to May 10, 1994

Wind Speed March 1 to 13, 1994

Wind Speed March 22 to May 10, 1994

Figure 3.1 Wind direction and speed on baseline and test sample days.

3.2 INHALABLE PARTICULATES

3.2.1 Characteristics

Air pollutants are not necessarily in gaseous form. Tiny particles of solid material are also present in the atmosphere and may constitute a pollution problem. These particles (and aerosols) range from 0.001 to 500 um (a human hair is about 100 um in diameter) and, depending on their size and other properties, remain suspended in the air for a few seconds or indefinitely.

In general, particles smaller than one micron in diameter originate in the atmosphere, primarily as a by-product of condensation and combustion. Particles between one and ten microns in diameter usually include soil, process dusts, and combustion products from industries. Particles larger than 10 microns in diameter generally result from mechanical processes such as wind erosion, grinding, spraying and vehicular activity.

Since particles enter the body through the respiratory system, most of their immediate effects are on this system. The factor which determines the depth of penetration into the respiratory system is the particle size. Larger particles tend to be deposited in the upper respiratory tract, such as the nose and throat, while smaller particles travel deeper into the lungs. The toxicity of the particles, however, varies with the chemical composition. Particles that can be inhaled are typically less than 10 microns in diameter.

Suspended particles may result from a variety of natural and anthropogenic sources. These sources include soil, road dust, dust resulting from other human activities (i.e. agriculture), smoke from forest fires, smoke from recreational sources (i.e. campfires and fireplaces), vehicle exhaust emissions, and industrial emission sources.

The guideline for total suspended particulate loadings is based on visibility reduction and nuisance effects. This guideline includes all suspended particulate matter, not only inhalable particles. Alberta has adopted the most rigorous federal standard as a guideline for total suspended particulates:

- 100 ug/m^3 (micrograms per cubic meter) as a 24-hour total loading; and
- 60 ug/m^3 as an annual geometric average loading.

At the present time, Alberta does not have a guideline for inhalable particulates.

3.2.2 Results

Inhalable particulates were measured by the dichotomous sampler in the fine (<2.5 um) and coarse (2.5 to 10 um) fractions in Canmore. Fine particulate loadings in Canmore ranged from 1.9 to 41.2 ug/m^3. The median fine particulate loading in Canmore (9.1 ug/m^3) was almost the same as the median observed in downtown Calgary in March and April (9.0 ug/m^3). Median coarse particulate loadings were about one-third of those recorded in downtown Calgary. Coarse particulate loadings in Canmore during the monitoring period ranged from 6.0 to 18.1 ug/m^3. Minimum, median and maximum fine and coarse particulate loadings are indicated in Tables 3.2 and 3.3. Median particulate loadings are also presented in Figure 3.2.

Particulate loadings at Canmore and the range of particulate loadings in downtown Calgary are illustrated in Figure 3.3. As indicated in these figures, fine particulate loadings in Canmore were higher than the median in downtown Calgary 47% of the time. The maximum fine particulate loading in downtown Calgary was exceeded in 5 of the 17 samples collected in Canmore. Coarse particulate loadings in Canmore were lower than the median in Calgary 82% of the time. Over half (53%) of coarse particulate loadings in samples from Canmore were lower than the minimum observed in downtown Calgary.

A cumulative frequency distribution of fine and coarse particulate loadings is presented in Figure 3.4. From these figures, it is evident that fine particulate loadings were higher in Canmore than downtown Calgary for the upper half of the frequency distribution. Coarse particulate loadings in Canmore were lower than those in Calgary for the entire frequency distribution.

The Mann-Whitney test was used to determine if differences between Canmore and Calgary downtown dichotomous samples are statistically significant. Prior to using this test, data for each sample set is sorted from lowest to highest and assigned a rank. The lowest value will have the lowest rank and the highest value will have the highest rank. This test combines the ranks of the data from the two data sets. The average rank for each data set is then calculated. The test statistic is based on a comparison of the average ranks for each data set. The results of this test are presented in Table 3.4. The results of this test show that fine particulate loadings in Canmore and Calgary are not significantly different. However, coarse particulate loadings were significantly higher at the Calgary downtown monitoring station than in Canmore.

Minimum, median and maximum fine and coarse particulate loadings for *baseline* and *test* samples are indicated in Table 3.3. Minimum, median and maximum loadings in the fine fraction were substantially higher in *baseline* samples than *test* samples. The opposite is evident for particulates in the coarse fraction. Minimum, median and maximum coarse particulate loadings are much higher in *test* samples. The median coarse particulate loading in *test* samples is about three times higher than the median in *baseline* samples.

3.3 ANIONS (sulphate, nitrate, chloride)

3.3.1 Characteristics

Anions are negatively charged groups of atoms or molecules formed when chemicals dissociate in water. For example, sulphuric acid and nitric acid produce sulphate and nitrate ions, respectively. Parent chemicals of many anions may be emitted into the atmosphere by gas

Table 3.2 Particulate loadings in Canmore and Calgary downtown dichotomous samples.

Parameter	Canmore			Calgary Downtown		
	Min	Med	Max	Min	Med	Max
Fine Particulate	1.9	9.1	41.2	5.0	9.0	19.0
Coarse Particulate	1.1	5.7	18.1	6.0	16.5	45.0

Table 3.3 Particulate loadings in Canmore baseline and test samples.

Parameter	Baseline			Test		
	Min	Med	Max	Min	Med	Max
Fine Particulate	1.9	11.0	41.2	5.1	7.3	11.3
Coarse Particulate	1.1	5.3	9.1	14.7	17.0	18.1

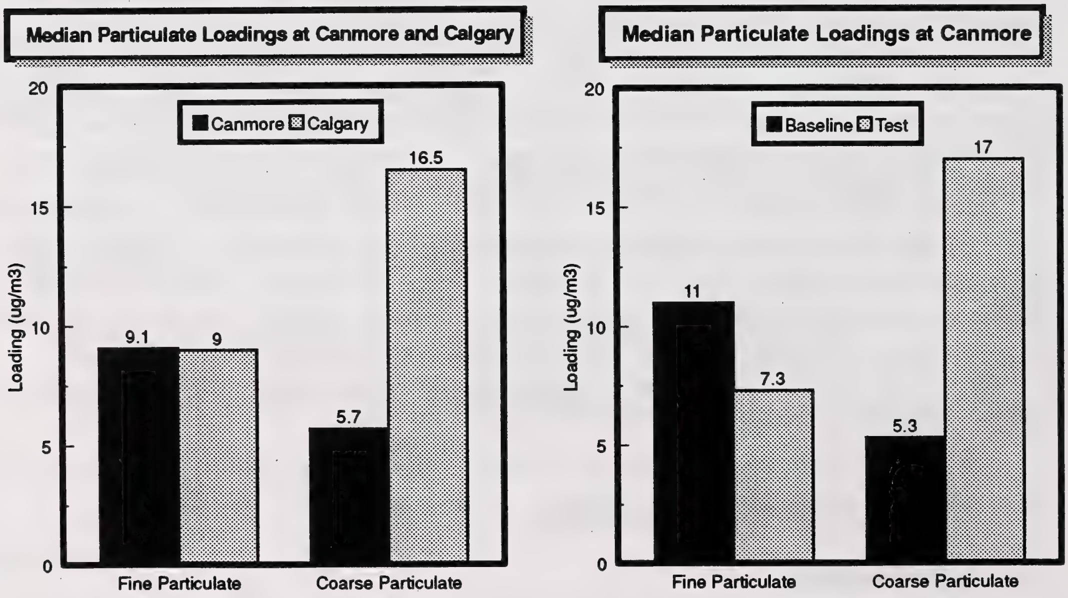
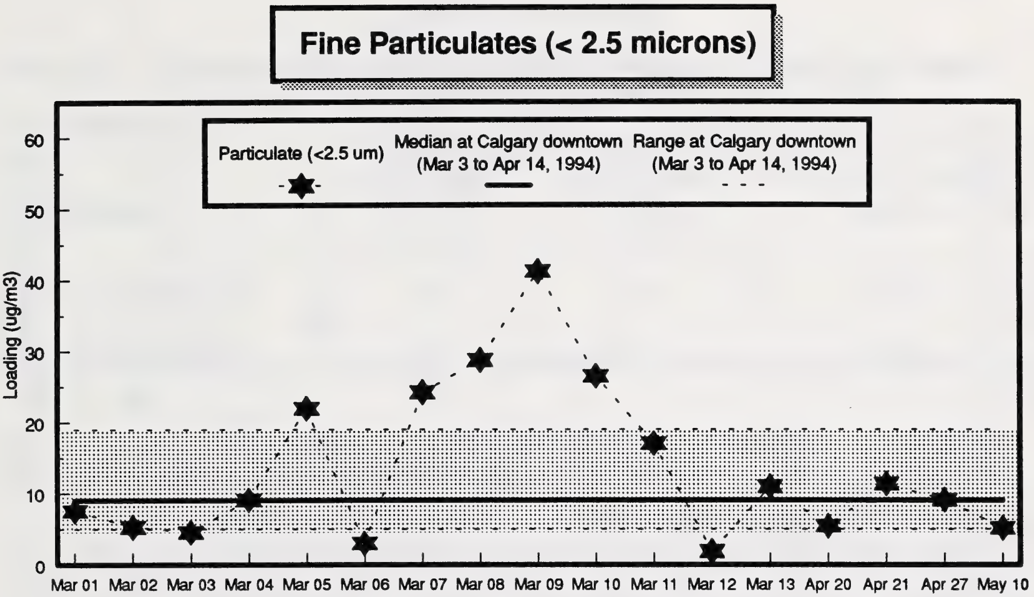


Figure 3.2 Median particulate loadings at Canmore and downtown Calgary.



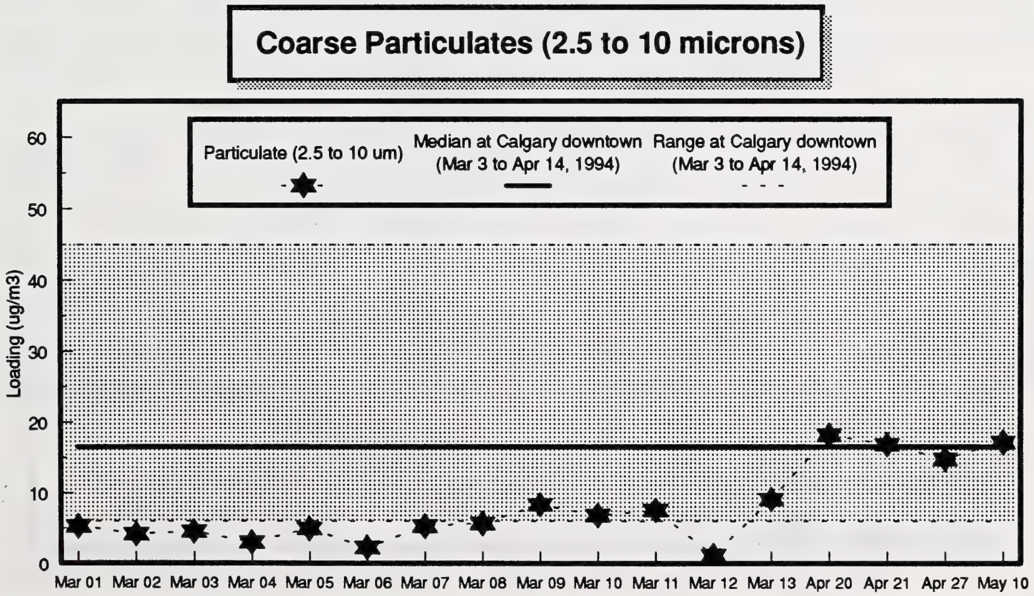
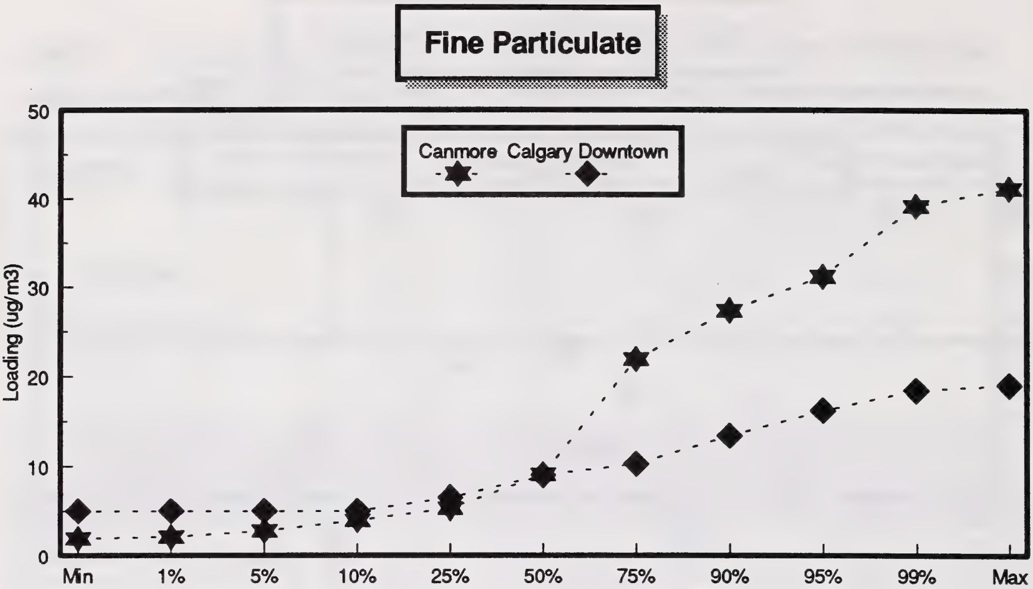


Figure 3.3 Fine and coarse particulate loadings at Canmore and downtown Calgary.


Fine Particulate

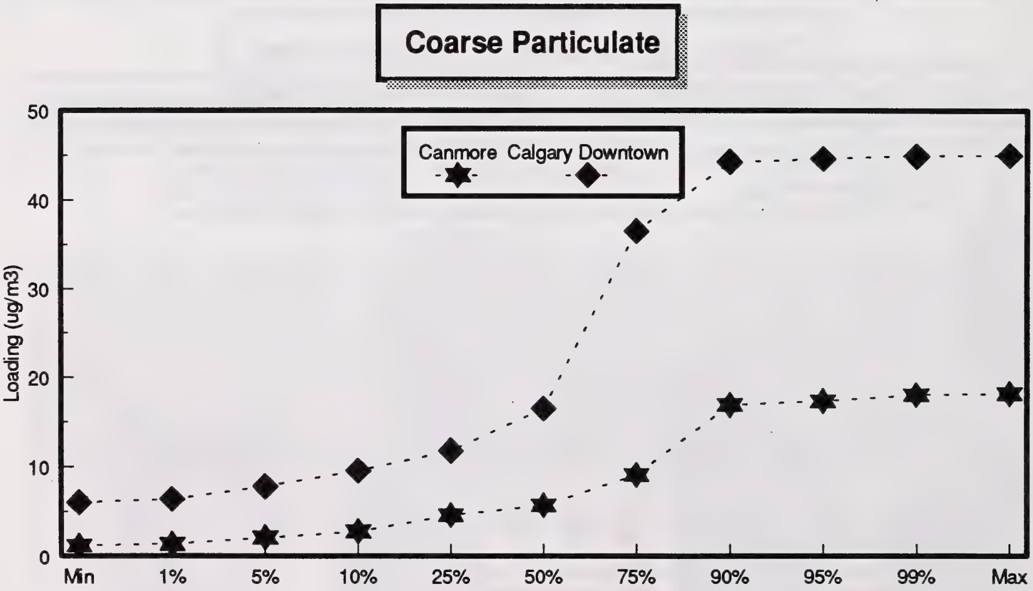

Coarse Particulate

Figure 3.4 Cumulative frequency distribution of fine and coarse particulate loadings from Canmore and Calgary.

Table 3.4 Comparison statistics for particulate loadings in Canmore and Calgary downtown dichotomous samples using the Mann-Whitney Test.

Parameter	Average Rank of Canmore Samples	Average Rank of Calgary Samples	Two-tailed Probability of Equalling
Fine Particulate	14.6	12.9	0.5979
Coarse Particulate	10.2	19.0	0.0056

plants, oil sands plants, coal-fired power plants, oil refineries, pulp and paper mills, fertilizer plants, cement plants and agricultural activities.

Sulphate is the fully oxidized form of sulphur oxides and other sulphur compounds. This oxidized ion will often be combined with other ions (cations) to form particulate sulphate. The primary sources of sulphur compounds in Alberta include natural gas processing facilities, oil sands facilities, power plants, oil refineries, pulp and paper mills, fertilizer plants, sulphur hot springs, sloughs and swamps. Dust from sulphur containing rocks and soil is a common natural source of particulate sulphate. Cement manufacturing operations will also produce sulphur oxides and particulate sulphate from the use of sulphur containing fuel and limestone which contains small amounts of sulphur. The major sources of sulphate in the Bow Corridor are likely wind-blown dust and particles emitted from the cement manufacturing operations.

Nitrate is the fully oxidized form of nitrogen oxides (including nitrogen dioxide, nitrous oxide and nitric oxide). As with sulphate, these oxidized ions will exist in combination with other ions (cations) to form particulate nitrate. The major sources of oxides of nitrogen in Alberta are natural gas processing facilities, transportation, power plants, natural gas and heating fuel use, agricultural fuel use, forest fires, residential wood burning, fertilizer plants and nitric acid plants. Wind-blown dust and soil will also contain particulate nitrate. Nitrates are also contained in particulates which may be emitted from cement manufacturing facilities and limestone mining operations. The majority of particulate nitrate monitored in the Canmore area likely originated from wind-blown dust, cement manufacturing operations and residential wood burning.

The most common sources of chloride in Alberta are wind-blown soil and road salt. Hydrogen chloride may be emitted from the incineration of refuse. The chloride ion will also exist in particulate matter originating from natural rock surfaces and is emitted in low concentrations from residential wood burning (U.S. Department of Energy, 1980).

3.3.2 Results

Chemical analysis for sulphate, nitrate and chloride was performed on particulate samples from the Canmore and Calgary downtown dichotomous samplers. Minimum, median and maximum concentrations of these anions are presented in Tables 3.5 and 3.6. Median anion concentrations are also indicated in Figure 3.5. Figures 3.6 to 3.8 show anion concentrations for Canmore samples and the range of anion concentrations observed in downtown Calgary in March and April.

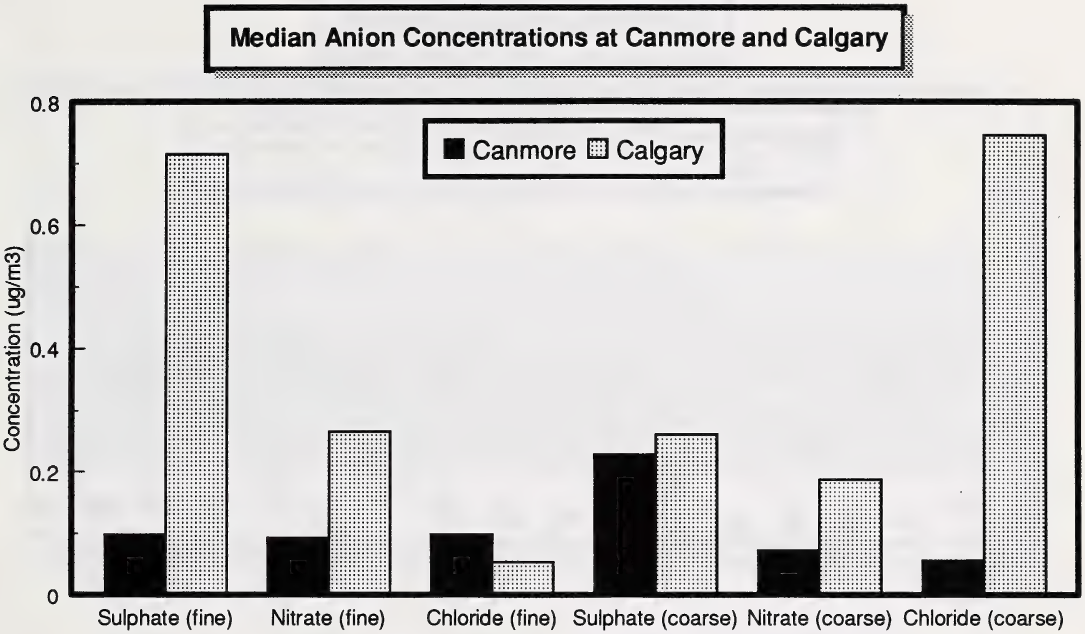
Median sulphate and nitrate concentrations in the fine fraction were substantially higher in downtown Calgary than Canmore. Median fine sulphate concentrations in Calgary were over seven time higher that the median value in Canmore. Fine chloride values in Canmore were higher than those observed in Calgary in March and April. The median fine chloride concentration in Canmore was close to twice as high as the median value in Calgary. Median nitrate and chloride concentrations in the coarse fraction were substantially higher in Calgary than in the Canmore samples. Median values of coarse sulphate were close to the same in Canmore and Calgary.

Table 3.5 Anion concentrations in Canmore and Calgary downtown dichotomous samples.

Parameter	**Fine Particulate (ug/m^3)**						**Coarse Particulate (ug/m^3)**					
	Canmore			**Calgary Downtown**			**Canmore**			**Calgary Downtown**		
	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
Sulphate	0.025	0.099	0.618	0.301	0.715	1.328	0.033	0.228	2.427	0.156	0.261	0.499
Nitrate	0.036	0.093	0.205	0.178	0.265	0.473	0.022	0.073	0.256	0.136	0.187	0.236
Chloride	0.023	0.099	0.218	0.017	0.053	0.231	0.026	0.056	0.160	0.377	0.746	3.670

Table 3.6 Anion concentrations in Canmore baseline and test samples.

Parameter	**Fine Particulate (ug/m^3)**						**Coarse Particulate (ug/m^3)**					
	Baseline Samples			**Test Samples**			**Baseline Samples**			**Test Samples**		
	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
Sulphate	0.025	0.094	0.236	0.123	0.140	0.618	0.033	0.225	0.095	0.405	0.667	2.427
Nitrate	0.036	0.093	0.141	0.069	0.125	0.205	0.022	0.065	0.198	0.185	0.240	0.256
Chloride	0.023	0.099	0.218	0.076	0.098	0.201	0.026	0.043	0.160	0.063	0.093	0.115


Median Anion Concentrations at Canmore and Calgary

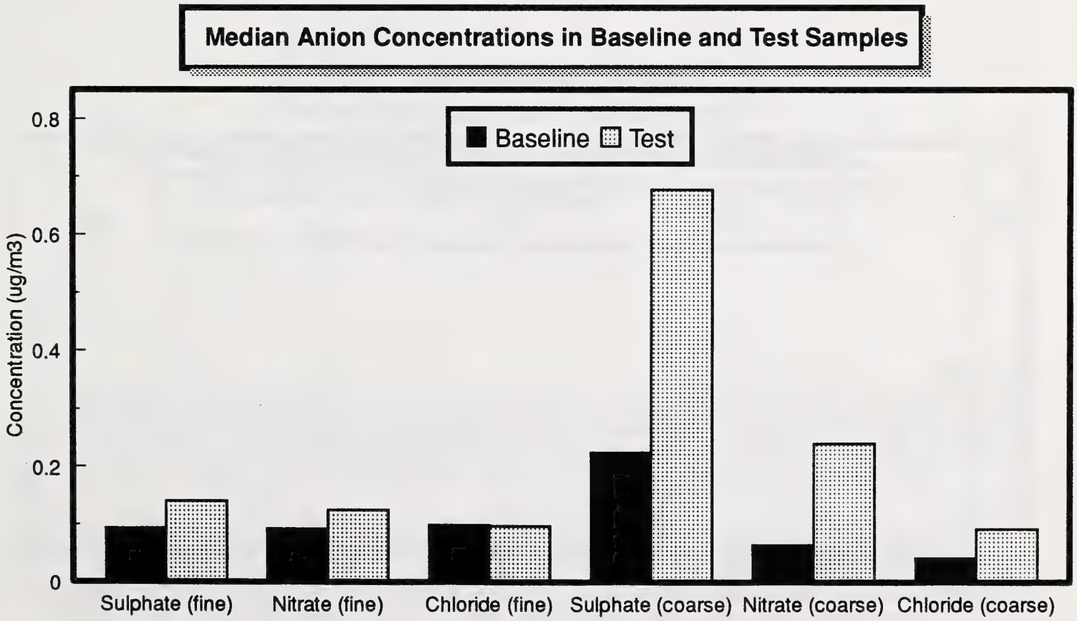
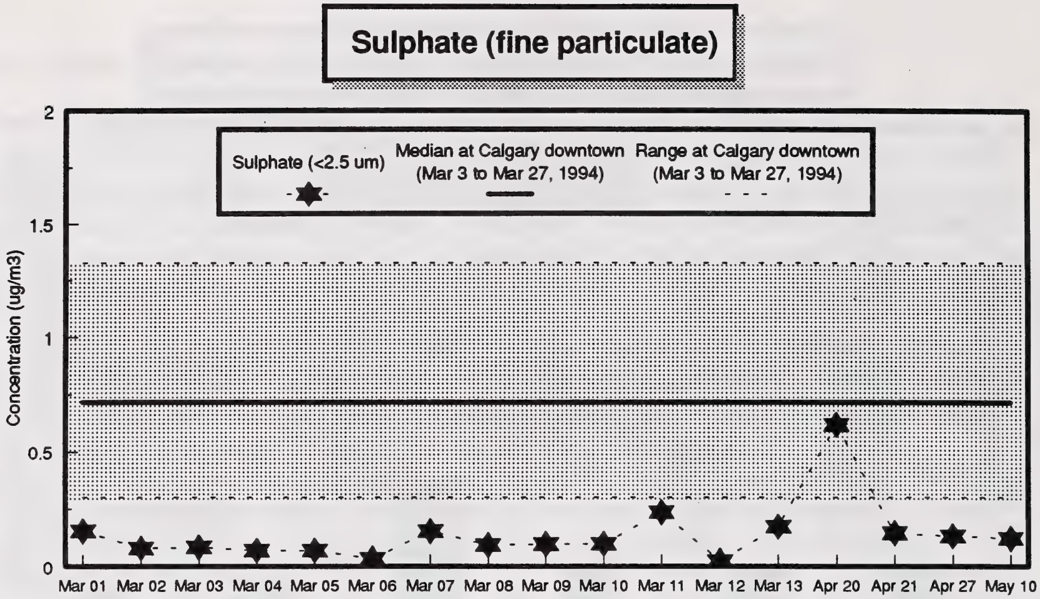

Median Anion Concentrations in Baseline and Test Samples

Figure 3.5 Median anion concentrations at Canmore and downtown Calgary.



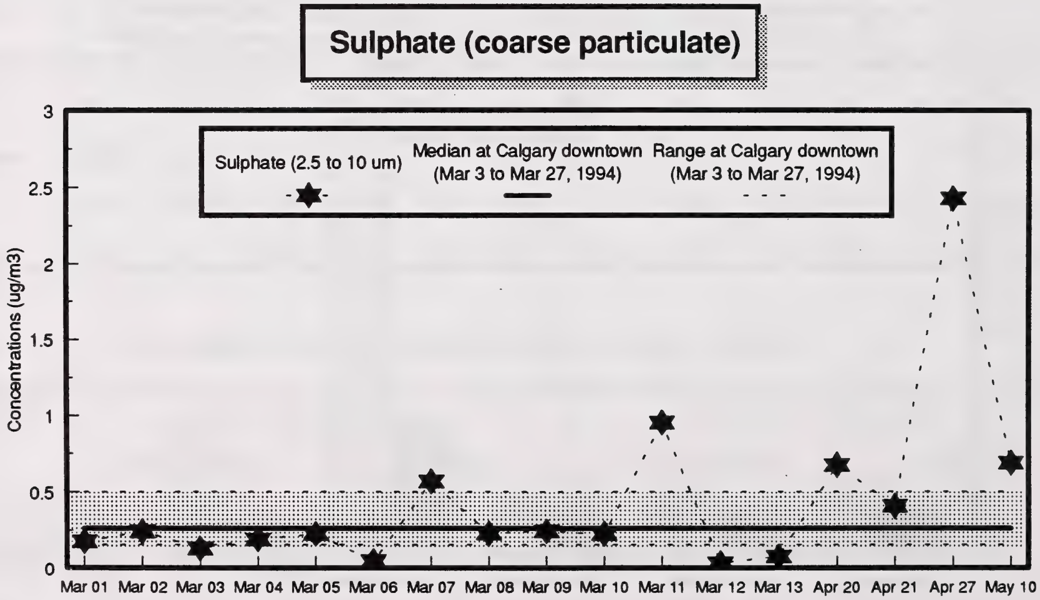
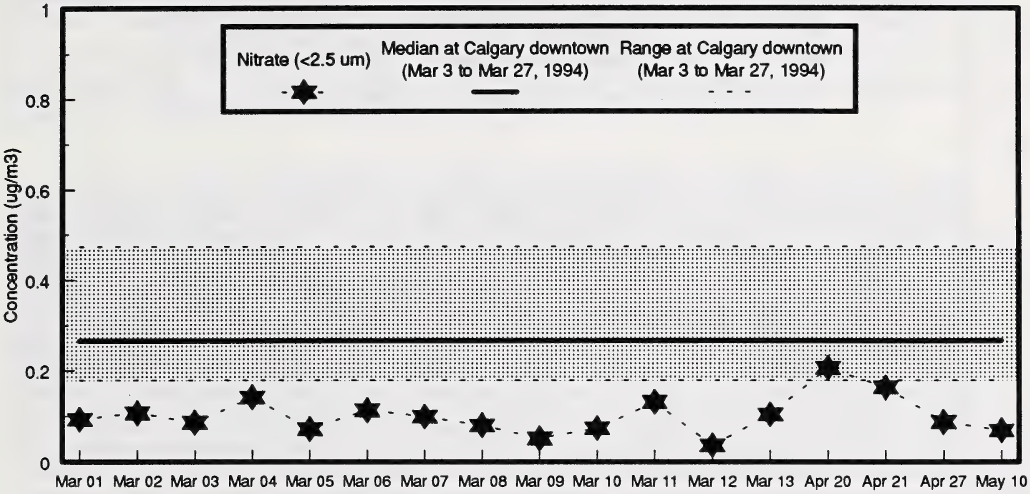


Figure 3.6 Sulphate concentrations at Canmore and downtown Calgary.

Nitrate (fine particulate)



Nitrate (coarse particulate)

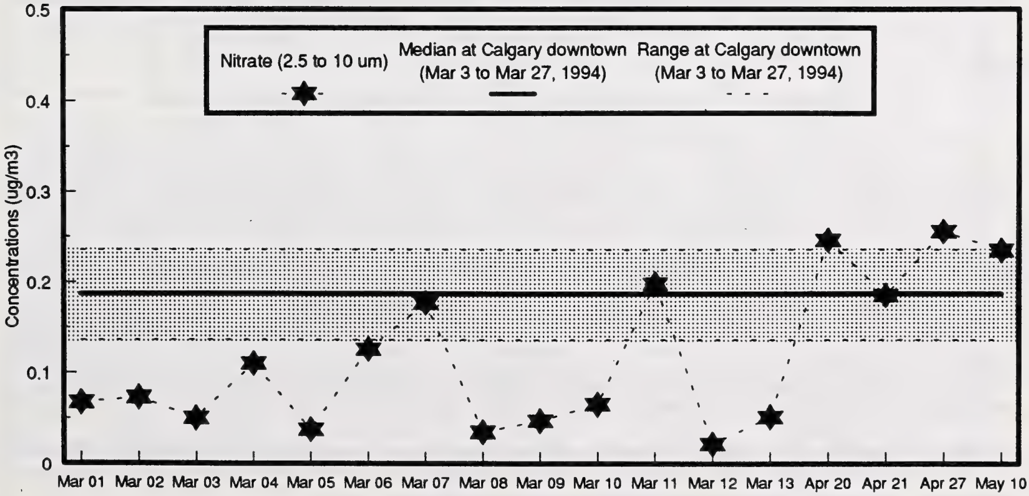
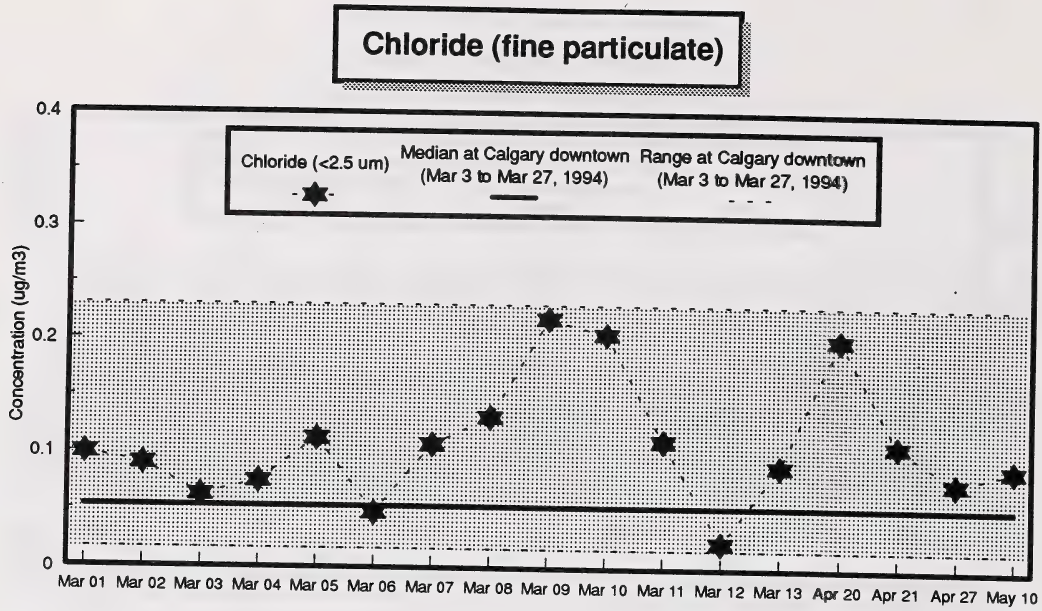


Figure 3.7 Nitrate concentrations at Canmore and downtown Calgary.



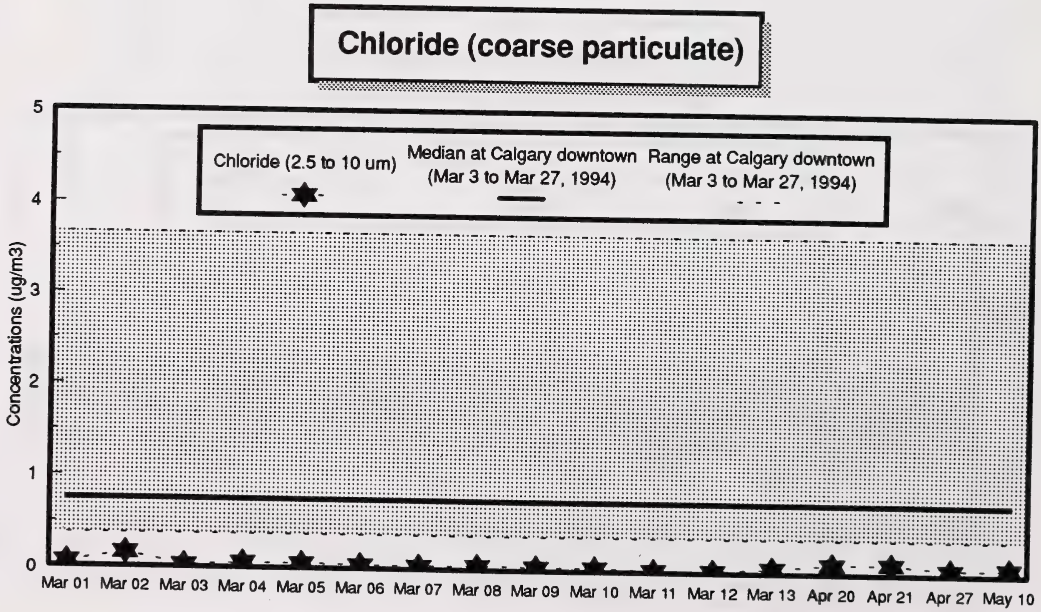


Figure 3.8 **Chloride concentrations at Canmore and downtown Calgary.**

As indicated in Figures 3.6 to 3.8, fine sulphate, fine nitrate and coarse chloride concentrations were lower than the median in downtown Calgary for all samples collected in Canmore. About 24% and 35% of coarse sulphate and nitrate samples, respectively, collected in Canmore had concentrations that were greater than the median at the Calgary downtown monitoring station. The majority (88%) of fine chloride samples had concentrations that were greater than the median in downtown Calgary.

Table 3.7 shows a comparison of anion concentrations in Canmore and downtown Calgary using the Mann-Whitney test. The results of this test show that concentrations of sulphate and nitrate in the fine fraction were significantly higher in Calgary samples than Canmore samples at a 95% level of confidence. Also, chloride concentrations in the coarse fraction were significantly higher in Calgary samples. Fine concentrations of chloride and coarse concentrations of sulphate and nitrate did not show a significant difference between Canmore and Calgary downtown samples.

Median sulphate and nitrate concentrations in the fine fraction were about 1.5 and 1.3 times higher in *test* samples than *baseline* samples. Median fine chloride values were close to the same in *baseline* and *test* samples. Coarse sulphate, nitrate and chloride concentrations were substantially higher in *test* samples. Median values of these parameters were 3, 3.7 and 2.2 times higher in *test* samples than *baseline* samples, respectively. With the exception of fine chloride, maximum fine and coarse concentrations of all anions were higher in *test* samples.

The major sources sulphates in the Canmore area are sulphur oxides released from industrial activities in Exshaw. Wind blown dust and the sour gas industry may also be a minor source of particulate sulphate. Oxides of nitrogen from vehicle exhaust and Exshaw industry are likely the major sources of nitrates in Canmore samples. Chloride contained in particulate samples is likely the result of wind-blown dust and, to a lesser extent, industries in the Exshaw area. Smoke from recreational wood burning may also be a source of these anions in Canmore.

Table 3.7 Comparison statistics for anion concentrations in Canmore and Calgary downtown dichotomous samples using the Mann-Whitney Test.

Parameter	Fine Particulates			Coarse Particulates		
	Average Rank of Canmore Samples	Average Rank of Calgary Samples	Two-tailed Probability of Equalling or Exceeding	Average Rank of Canmore Samples	Average Rank of Calgary Samples	Two-tailed Probability of Equalling
Sulphate	9.1	20.2	0.0007	11.2	12.6	0.6953
Nitrate	10.1	17.5	0.0229	10.3	15.6	0.1171
Chloride	12.6	7.6	0.1366	9.0	20.0	0.0010

3.4 CATIONS (calcium, ammonium, sodium, magnesium, potassium)

3.4.1 Characteristics

Cations are positively charged groups of atoms formed when chemical compounds dissociate in water. All solutions are electronically neutral and, therefore, each anion will be balanced by a cation. Many parent chemicals will emanate from industrial sources such as iron, steel, wood, coal and cement manufacturing. A large percentage of cations are also contained in: wind-blown soil and dust; and smoke from recreational wood burning and forest fires. Cations measured were calcium, ammonium, sodium, magnesium and potassium.

The most common natural sources of calcium are wind-blown dust and road dust. Road salt (calcium chloride) is also a common source of calcium. Cement manufacturing operations are a primary source of particulate calcium in the Bow Corridor. Calcium, in the form of calcium oxide, is emitted as particulate matter from processes used in iron and steel manufacturing. Calcium oxide is also a major constituent of coal emissions (Fidalgo et al., 1988; Trier and Silva, 1987; Environment Canada, 1984). Calcium is also emitted from recreational wood burning and forest fires.

The major anthropogenic sources of ammonia are fertilizer plants and fertilizer application. Some natural sources of ammonia include plant and animal decay, and animal by-products. Ammonium may also be contained, to a lesser extent, in particulate matter from rock surfaces and emissions from cement manufacturing facilities.

Sodium is a component of wind-blown dust in rocky environments. Rock surfaces in mountainous areas are composed of natural salts. Magnesium and sodium are contained in particle dust resulting from processing of rock which contains magnesium and sodium. Smoke from burning wood also contains sodium and magnesium.

Potassium is a major constituent in the fly ash resulting from the burning of fossil fuels such as coal. Wood ash produced by forest fires, recreational fires, wood manufacturing and cement manufacturing industries contain significant quantities of potassium. Potassium occurs naturally in wind blown soil and road dust (Fidalgo et al., 1988; Environment Canada, 1984)

3.4.2 Results

Particulate samples from Canmore and downtown Calgary underwent chemical analysis for calcium, ammonium, sodium, magnesium and potassium. Minimum, median and maximum cation concentrations are indicated in Tables 3.8 and 3.9. Median cation concentrations are also illustrated in Figure 3.9.

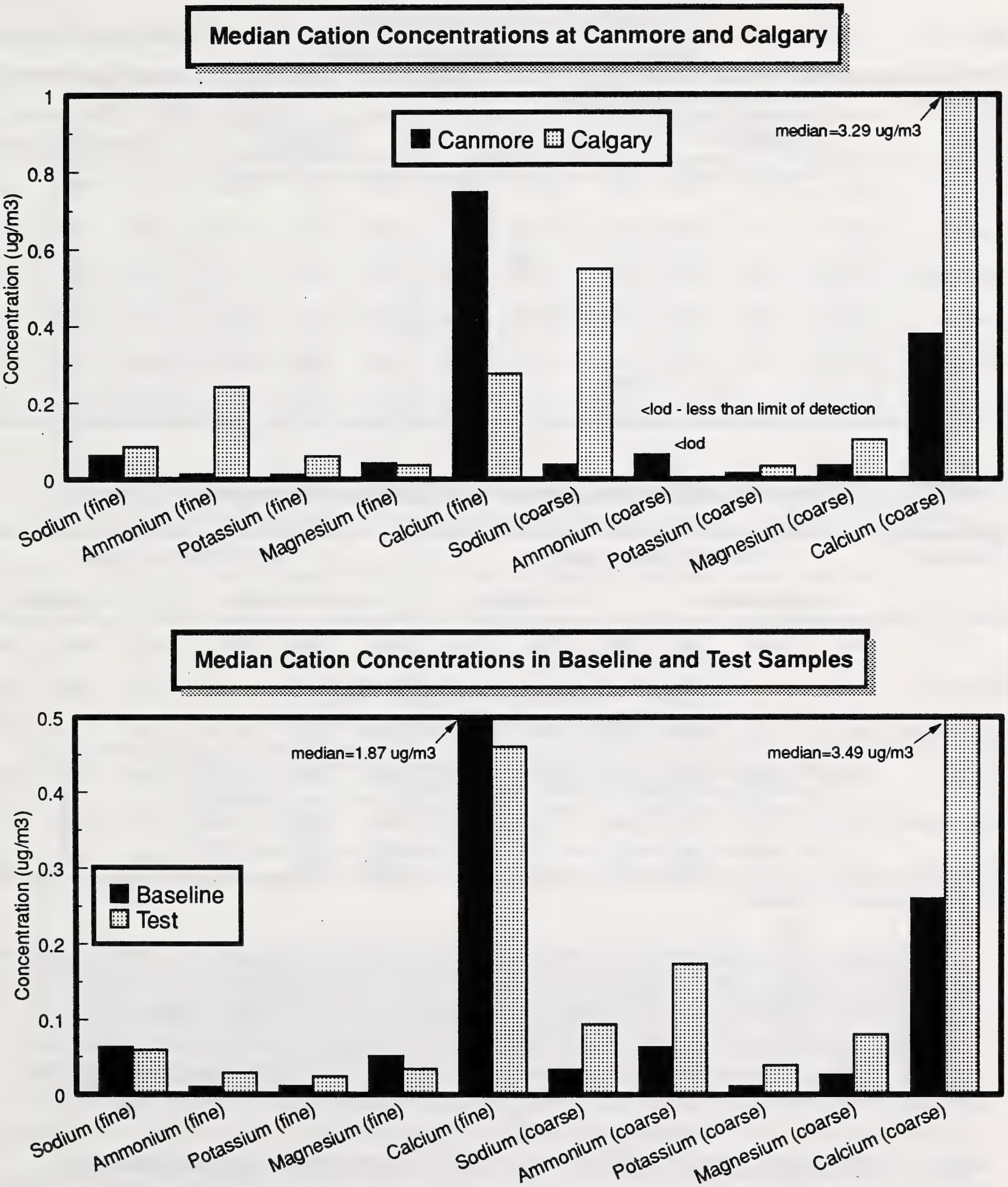


Figure 3.9 Median cation concentrations at Canmore and downtown Calgary.

Table 3.8 **Cation concentrations in Canmore and Calgary downtown dichotomous samples.**

Parameter	Fine Particulate (ug/m^3)						Coarse Particulate (ug/m^3)					
	Canmore			Calgary Downtown			Canmore			Calgary Downtown		
	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
Calcium	0.255	0.747	6.928	0.152	0.276	0.358	0.096	0.379	4.595	1.300	3.290	3.970
Ammonium	0.002	0.015	0.038	0.052	0.242	0.594	0.001	0.064	0.714	<lod	<lod	0.013
Sodium	0.013	0.063	0.152	0.055	0.085	0.204	0.015	0.038	0.265	0.262	0.548	2.428
Magnesium	0.010	0.042	0.117	0.030	0.037	0.038	0.009	0.036	0.085	0.070	0.103	0.116
Potassium	0.005	0.013	0.361	0.038	0.061	0.090	0.005	0.016	0.091	0.013	0.034	0.050

Table 3.9 **Cation concentrations in Canmore baseline and test samples.**

Parameter	Fine Particulate (ug/m^3)						Coarse Particulate (ug/m^3)					
	Baseline Samples			Test Samples			Baseline Samples			Test Samples		
	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
Calcium	0.255	1.867	6.928	0.407	0.461	2.619	0.096	0.260	1.102	2.572	3.486	4.595
Ammonium	0.002	0.010	0.036	0.020	0.029	0.038	0.001	0.063	0.307	0.119	0.174	0.714
Sodium	0.013	0.063	0.128	0.045	0.059	0.152	0.015	0.033	0.265	0.060	0.094	0.106
Magnesium	0.010	0.051	0.117	0.034	0.034	0.050	0.009	0.026	0.048	0.071	0.080	0.085
Potassium	0.005	0.011	0.020	0.014	0.024	0.361	0.005	0.011	0.091	0.032	0.039	0.045

<lod - less than limit of detection

Calcium concentrations in the fine fraction were substantially higher in Canmore samples than Calgary samples. The median fine calcium concentration in Canmore was 2.7 times higher in Canmore samples then Calgary samples. Fine magnesium also recorded a median value in Canmore samples that was slightly higher than Calgary samples. Median sodium, ammonium and potassium concentrations in the fine fraction were higher in Calgary downtown samples than Canmore samples. However, the overall peak fine potassium concentration was higher in Canmore samples. With the exception of ammonium, concentrations of all cations in the coarse fraction were higher in Calgary downtown samples than Canmore samples. Although, maximum values of coarse calcium, potassium and ammonium were higher in Canmore samples.

Figures 3.10 to 3.14 show cation concentrations in Canmore samples and the range of cation concentrations in Calgary samples collected in March and April. Fine particulate concentrations of ammonium, potassium and sodium in Canmore were lower than the median at

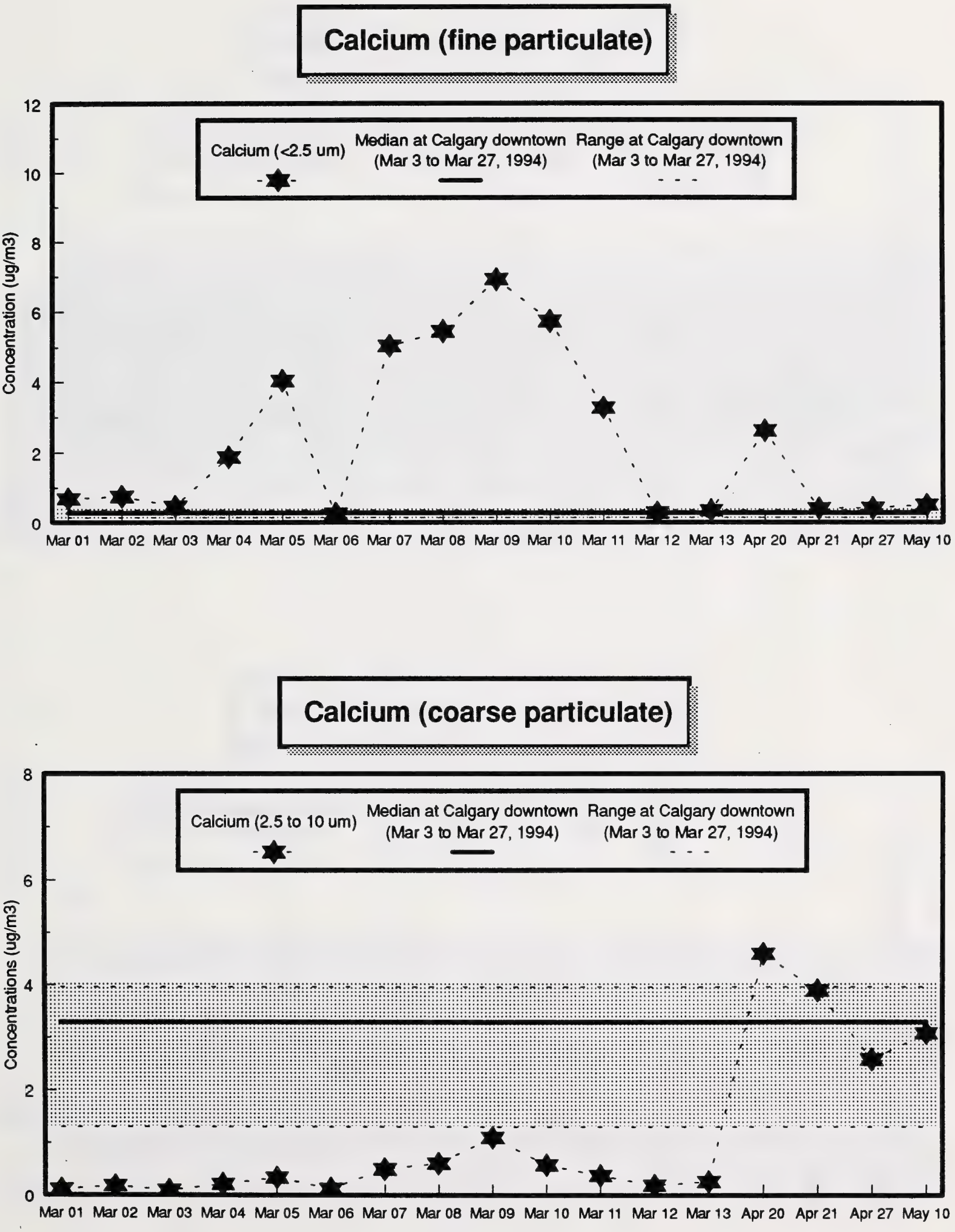
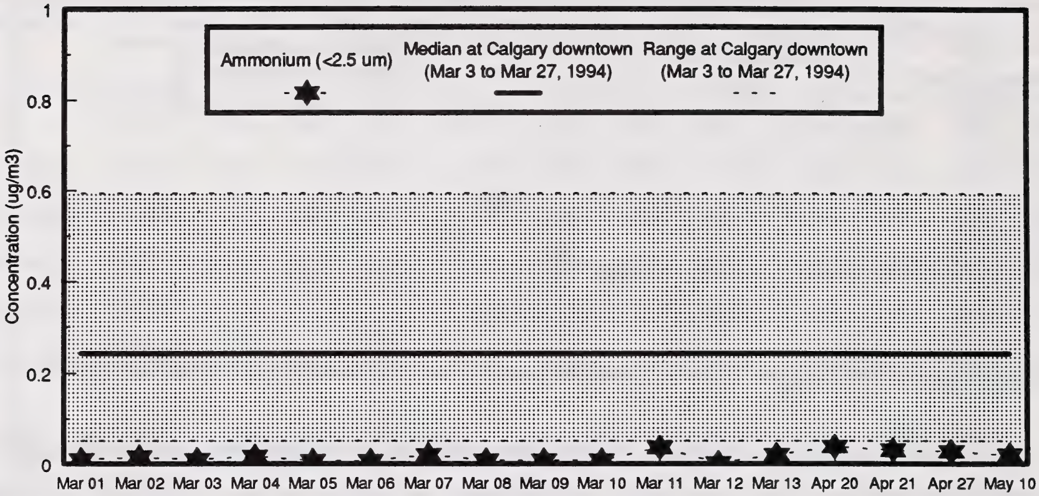
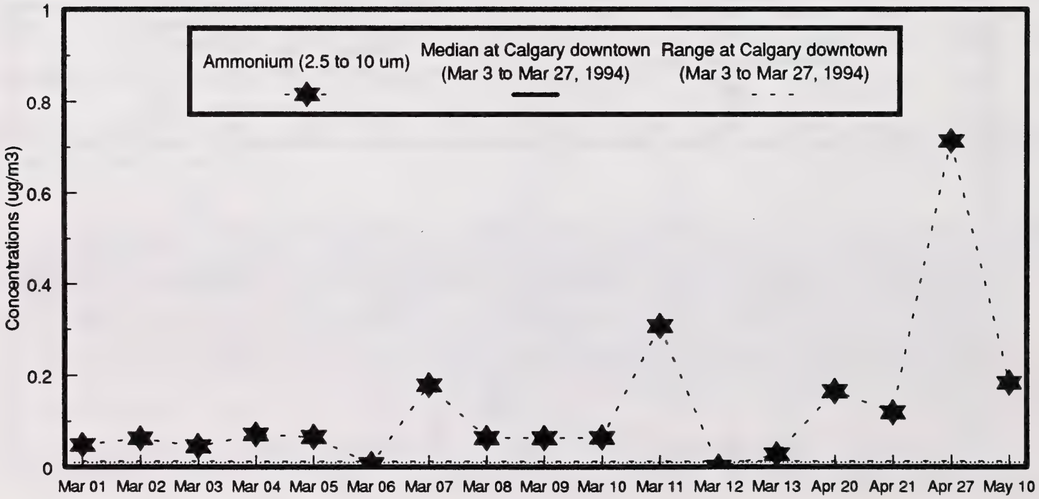


Figure 3.10 Calcium concentrations at Canmore and downtown Calgary.

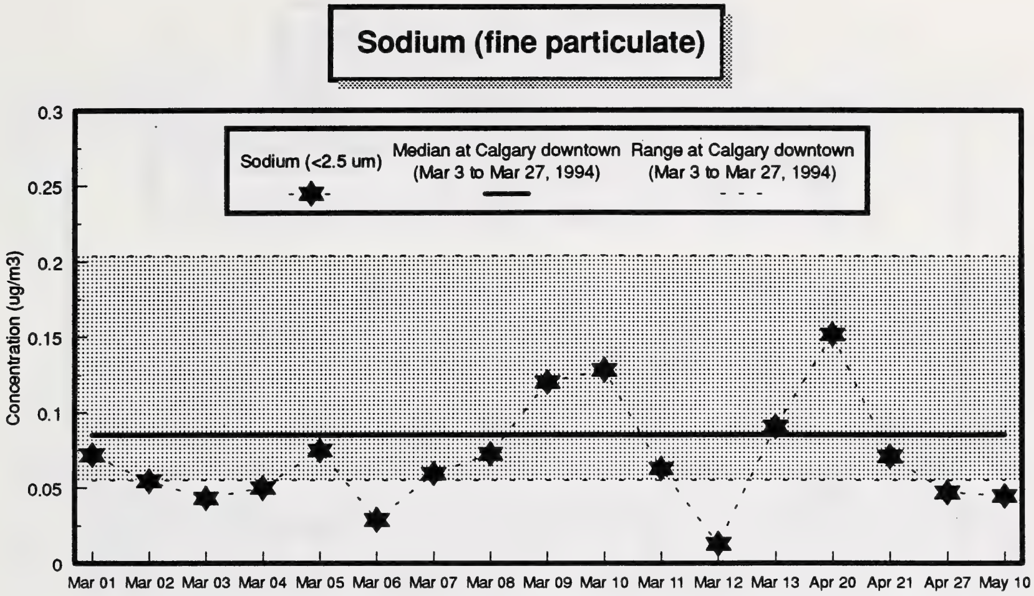


Ammonium (fine particulate)



Ammonium (coarse particulate)

Figure 3.11 Ammonium concentrations at Canmore and downtown Calgary.



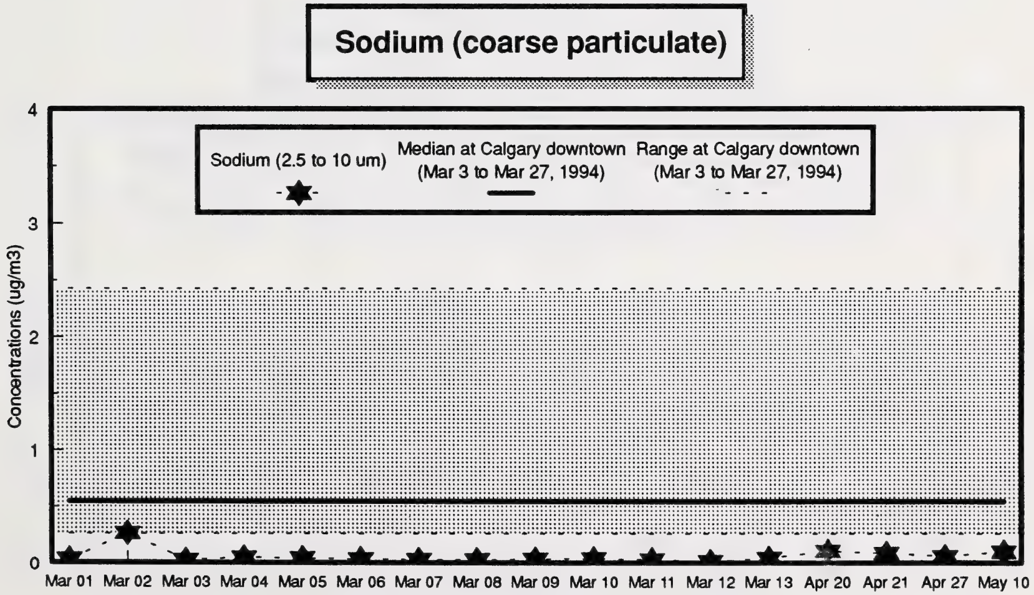


Figure 3.12 Sodium concentrations at Canmore and downtown Calgary.

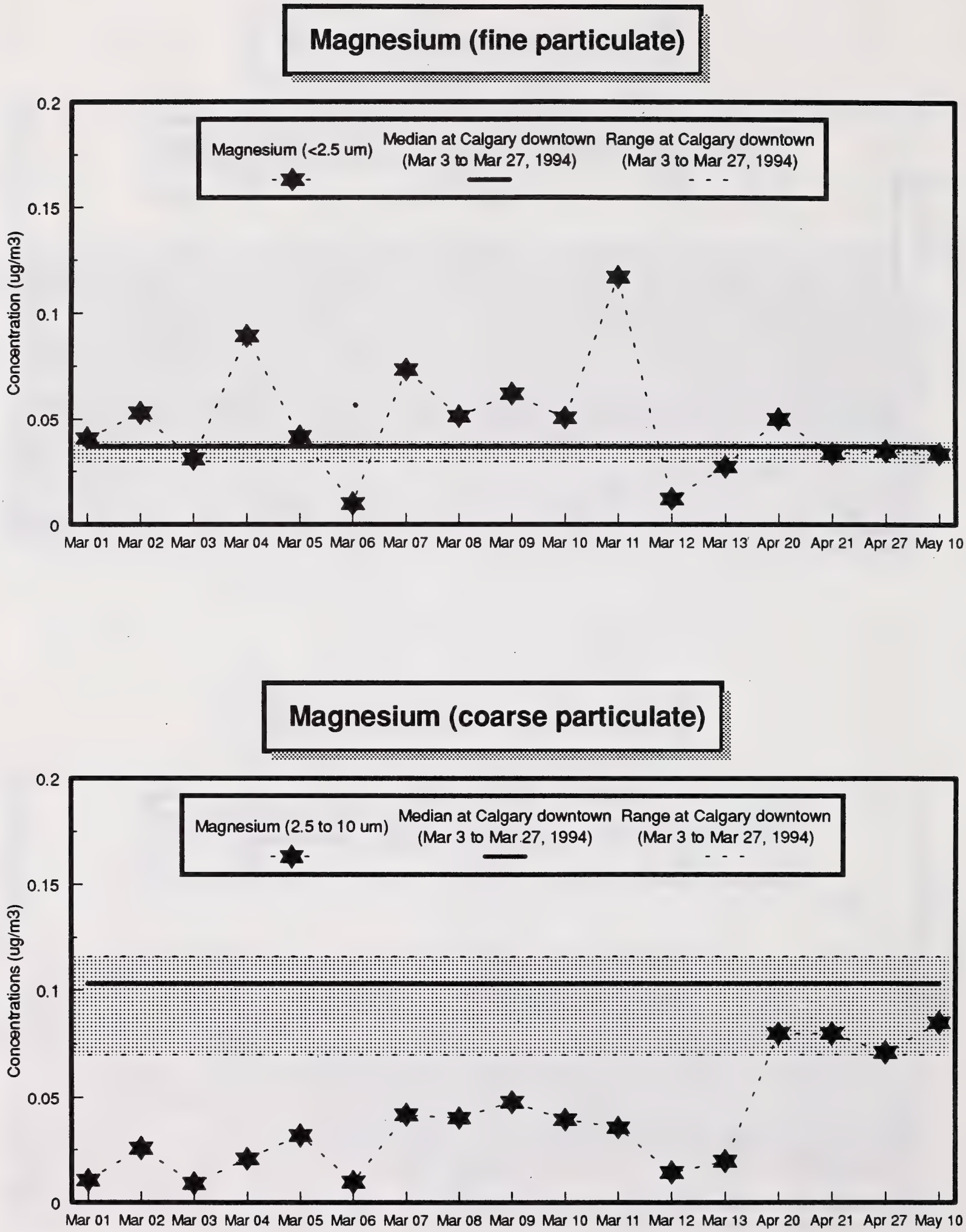


Figure 3.13 Magnesium concentrations at Canmore and downtown Calgary.

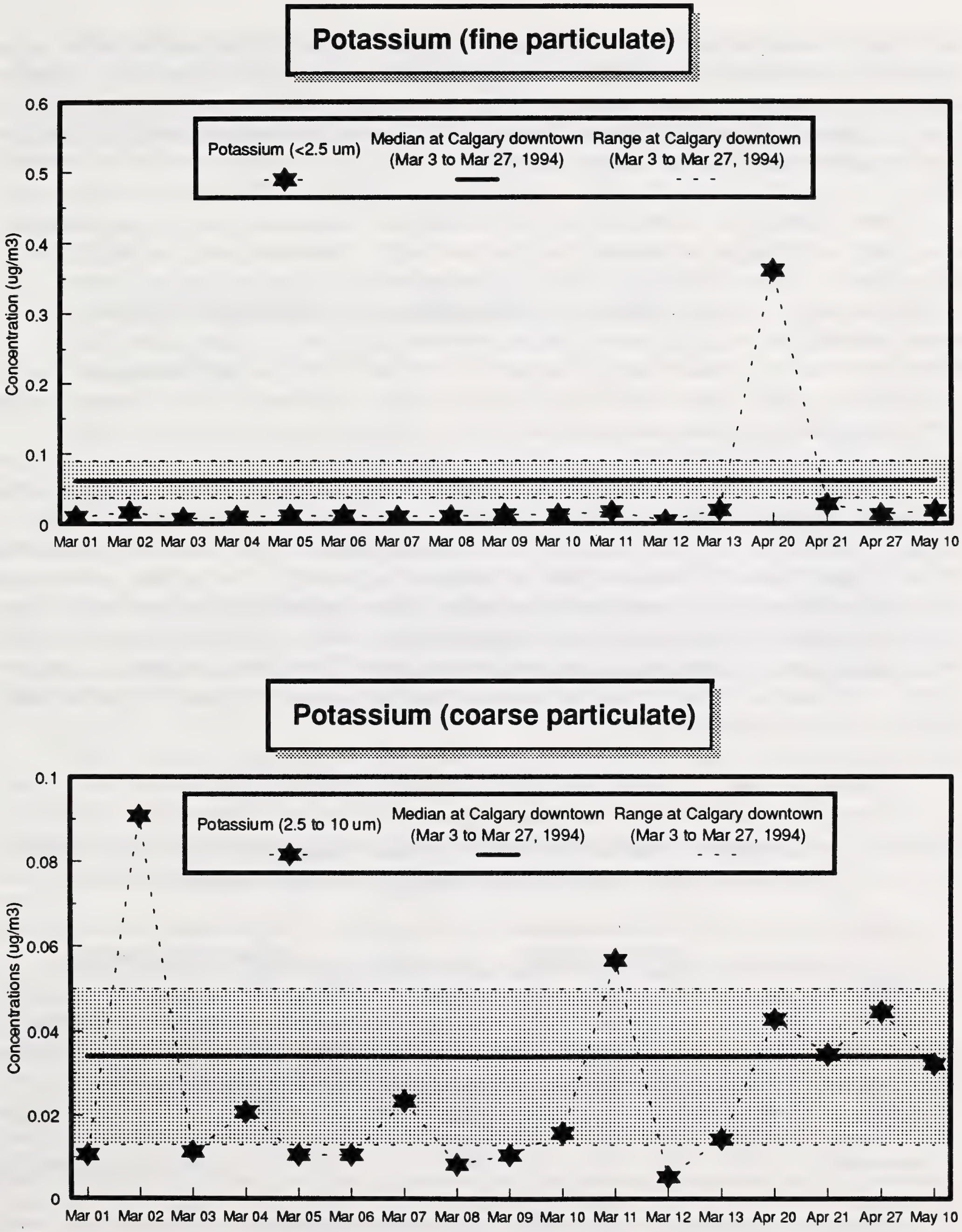


Figure 3.14 Potassium concentrations at Canmore and downtown Calgary.

the Calgary downtown station most of the time. Calcium and magnesium concentrations in the fine fraction were above the median in Calgary 88 and 59% of the time, respectively. Calcium, sodium, magnesium and potassium concentrations in the coarse fraction were lower in Canmore than Calgary most of the time. Coarse ammonium concentrations were higher in all Canmore samples than the median in downtown Calgary.

From Table 3.10 it is evident that fine calcium and coarse ammonium concentrations were significantly higher in Canmore samples than Calgary downtown samples (at a 95% level of confidence). Concentrations of ammonium and potassium in the fine fraction showed significantly higher values in Calgary downtown samples. Concentrations of calcium, magnesium and sodium in the coarse fraction were also significantly higher at the Calgary downtown monitoring station than in Canmore. Statistically significant differences in concentrations of fine magnesium, fine sodium and coarse potassium were not detected between Canmore and Calgary downtown samples.

Median fine particulate concentrations of ammonium and potassium were higher in *test* than *baseline* samples. Median values of these ions were 2.9 and 2.2 times higher in *test* samples, respectively. Median values of calcium and magnesium in the fine fraction were 4 and 1.5 times higher in *baseline* samples than *test* samples, respectively. Fine sodium concentrations were close to the same in *test* and *baseline* samples. Concentrations of all cations in the coarse fraction were higher in *test* samples than *baseline* samples. Median concentrations of coarse sodium, ammonium, potassium and magnesium were from 2.8 to 3.5 times higher in *test* samples. The median coarse calcium value in *test* samples was over 13 times higher than the median value in *baseline* samples.

Table 3.10 Comparison statistics for cation concentrations in Canmore and Calgary downtown dichotomous samples using the Mann-Whitney Test.

Parameter	Fine Particulates			Coarse Particulates		
	Average Rank of Canmore Samples	Average Rank of Calgary Samples	Two-tailed Probability of Equalling	Average Rank of Canmore Samples	Average Rank of Calgary Samples	Two-tailed Probability of Equalling
Calcium	13.6	4.2	0.0048	9.8	17.4	0.0231
Ammonium	9.0	20.0	0.0010	13.8	3.8	0.0029
Sodium	11.1	14.7	0.2778	9.1	19.8	0.0013
Magnesium	12.2	9.2	0.3887	9.1	19.2	0.0017
Potassium	9.2	18.5	0.0082	10.8	13.8	0.3873

Many of the cations measured in Canmore are present in the natural environment. For example calcium, ammonium, sodium, magnesium and potassium are contained in the rock and soil in the Canmore and Exshaw areas. Elevated cation concentrations in *test* samples may be related to: (a) stack emissions from the Exshaw area; (b) transport of dust generated by industrial activities in the Exshaw area; or (c) decreased dispersion because of light winds. Potassium, calcium, sodium and magnesium may also result from wood burning in the Canmore/Exshaw region.

3.5 POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

3.5.1 Characteristics

PAHs are organic compounds that are formed during the combustion of organic materials. Some of these compounds include benzo (a) pyrene (B(a)P), benzo (k) fluoranthene (B(k)F), pyrene, fluoranthene, phenanthrene, fluorene, naphthalene, anthracene and acenaphthene. Many of these compounds have been identified as air toxics or potential carcinogens.

Most sources of PAHs have not been accurately characterized because of the variety of factors that influence PAH formation. For example, during the process of combustion, the amount of excess air, combustion temperature, fuel moisture content and feed conditions will affect the formation of PAHs.

PAHs, such as B(a)P, are present in all types of soot and smoke. The major sources of some PAHs are motor vehicle emissions, residential wood combustion, heat and power generation, coke production and refuse burning. PAHs have also been detected in tobacco smoke, wood smoke from recreational fires (campfires and fireplaces), forest fires, food stuffs such as smoked fish, charcoal broiled steak, roasted coffee, vegetables and cereals (Jones et al., 1987).

Motor vehicle emissions have been cited as the major source of PAHs in the United States (Bjorseth and Ramdahl, 1985). A major component of diesel fuel exhaust emission is phenanthrene. Anthracene, fluoranthene, pyrene, B(k)F and B(a)P are also contained in diesel and gasoline exhaust emissions (Westerholm and Li, 1994; Rogge et al., 1993). These PAHs have also been found to be contained in fine organic aerosols originating from tire wear particles, brake lining particles and road dust particles. Tire wear, brake lining and road dust particles are considered major sources of organic carbon in the fine fraction (Rogge et al., 1993; Hildermann et al., 1991).

Recreational wood burning and forest fires are sources of many PAHs. Some PAHs which have been identified in wood smoke include fluorene, anthracene, fluoranthene, pyrene, B(a)P, acenaphthene and phenanthrene (U.S. Department of Energy, 1980; Hawthorne et al., 1988).

Concentrations of PAHs are obtained by high pressure chromatography analysis of SSI and high volume filters. The result is a 24-hour concentration expressed in units of micrograms per 1000 cubic meters or nanograms per cubic meter (ng/m^3). Alberta currently does not have guidelines for PAHs.

The most commonly measured PAH in Alberta is B(a)P. Concentrations of B(a)P are recorded routinely at several locations in the province. In 1993, annual average B(a)P concentrations ranged from 0.05 to 0.24 ng/m^3 at Alberta Environmental Protection monitoring stations. Average B(a)P concentrations in March and April ranged from 0.03 to 0.18 ng/m^3. The highest B(a)P concentrations are generally recorded in the downtown cores of Calgary and Edmonton where vehicle exhaust emissions are the major source (Myrick, 1994).

3.5.2 Results

Chemical analysis for nine major PAHs was conducted on particulate samples from Canmore and Calgary. These PAHs included benzo (a) pyrene (B(a)P), benzo (k) fluoranthene (B(k)F), pyrene, fluoranthene, phenanthrene, fluorene, naphthalene, anthracene and acenaphthene. Median and maximum concentrations for these PAHs are presented in Tables 3.11 and 3.12. Median values are also represented in Figure 3.15. PAH concentrations for individual samples are illustrated in Figures 3.16 to 3.18.

Median concentrations of naphthalene, anthracene and acenaphthene were below the analytical detection limits in Canmore SSI and Calgary high volume samples. Median values of fluoranthene, phenanthrene and fluorene were higher in the Canmore SSI samples than the Calgary high volume samples. Median concentrations of B(a)P, B(k)F and pyrene were higher in Calgary high volume samples. Fluoranthene and phenanthrene had median concentrations that were less than the analytical detection limit at Calgary downtown compared to values of 0.036 and 0.217 ng/m^3, respectively, at Canmore. Fluorene concentrations were 85% higher in Canmore SSI samples than Calgary downtown high volume samples.

As indicated in Figures 3.16, concentrations of B(a)P, B(k)F and Pyrene were below the median concentration in Calgary downtown for all Canmore samples. Figures 3.17 and 3.18 show that fluoranthene, phenanthrene, naphthalene and anthracene were detected at levels above the median in downtown Calgary for several Canmore SSI samples. However, as mentioned earlier, the median for many of these parameters was below the analytical detection limit in Calgary samples. Fluoranthene and phenanthrene concentrations in Canmore SSI samples were above the median in downtown Calgary (analytical detection limit) at least 90% of the time. Fluorene values were above the median in downtown Calgary in 12 of 20 samples. Naphthalene and anthracene concentrations were higher than the median in downtown Calgary (analytical detection limit) in 30% of the samples.

Baseline samples collected from March 1 to 13 in Canmore contained higher median concentrations of B(k)F, phenanthrene and fluorene than median concentrations in *test* samples.

Table 3.11 PAH concentrations in Canmore SSI and Calgary downtown high volume samples.

Parameter	Canmore			Calgary Downtown		
	Min	Med	Max	Min	Med	Max
B(a)P	<lod	0.039	0.205	0.092	0.396	0.599
B(k)F	<lod	0.015	0.187	0.093	0.236	0.315
Pyrene	0.005	0.089	0.162	0.234	0.684	0.815
Fluoranthene	<lod	0.036	0.098	<lod	<lod	0.402
Phenanthrene	<lod	0.217	0.640	<lod	<lod	0.445
Fluorene	<lod	0.586	1.591	0.245	0.316	0.363
Naphthalene	<lod	<lod	0.010	<lod	<lod	<lod
Anthracene	<lod	<lod	0.011	<lod	<lod	<lod
Acenaphthene	<lod	<lod	0.655	<lod	<lod	<lod

Table 3.12 PAH concentrations in Canmore baseline and test samples.

Parameter	Baseline Samples			Test Samples		
	Min	Med	Max	Min	Med	Max
B(a)P	<lod	0.039	0.205	0.004	0.039	0.051
B(k)F	<lod	0.043	0.187	<lod	<lod	<lod
Pyrene	0.005	0.096	0.162	0.030	0.089	0.126
Fluoranthene	<lod	0.031	0.065	0.031	0.083	0.098
Phenanthrene	<lod	0.385	0.640	0.038	0.083	0.210
Fluorene	<lod	0.896	1.591	0.040	0.069	0.126
Naphthalene	<lod	<lod	<lod	0.004	0.009	0.010
Anthracene	<lod	<lod	<lod	0.002	0.006	0.011
Acenaphthene	<lod	<lod	0.655	<lod	<lod	<lod

<lod - less than limit of detection

Median values of B(a)P and pyrene were close to the same in *baseline* and *test* samples. Fluoranthene, naphthalene and anthracene had higher median concentrations in *test* samples. Median concentrations of phenanthrene and fluorene were 4.6 and 13 times higher in *baseline* samples than *test* samples. The median fluoranthene concentration was 2.7 times higher is *test* samples than *baseline* samples. Median values of naphthalene and anthracene were below the analytical detection limit in *baseline* samples compared to median values of 0.009 and 0.006 ng/m^3, respectively, in *test* samples. Acenaphthene concentrations were below the analytical detection limit in 12 of 13 *baseline* samples and all *test* samples.

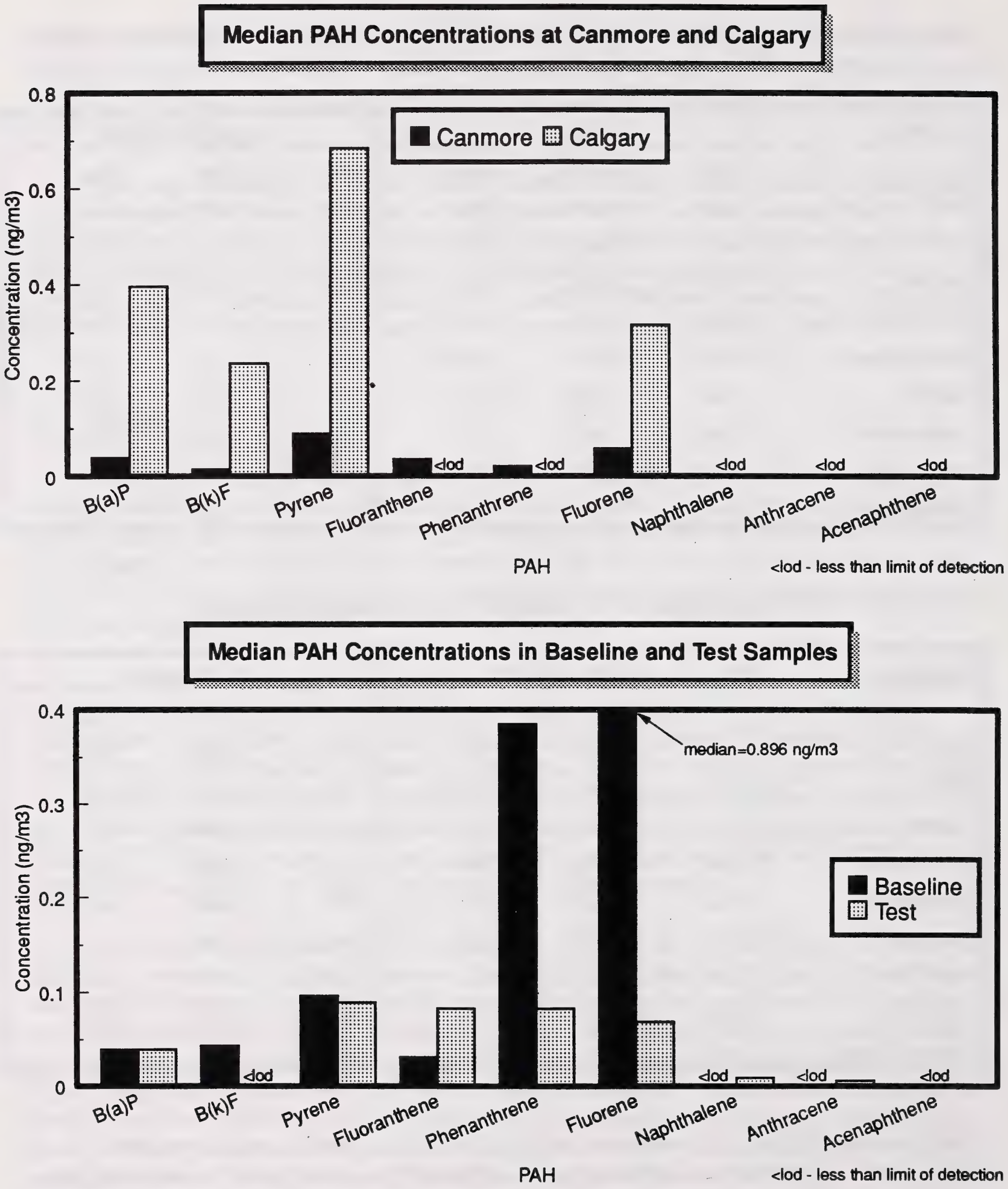


Figure 3.15 Median PAH concentrations at Canmore and downtown Calgary.

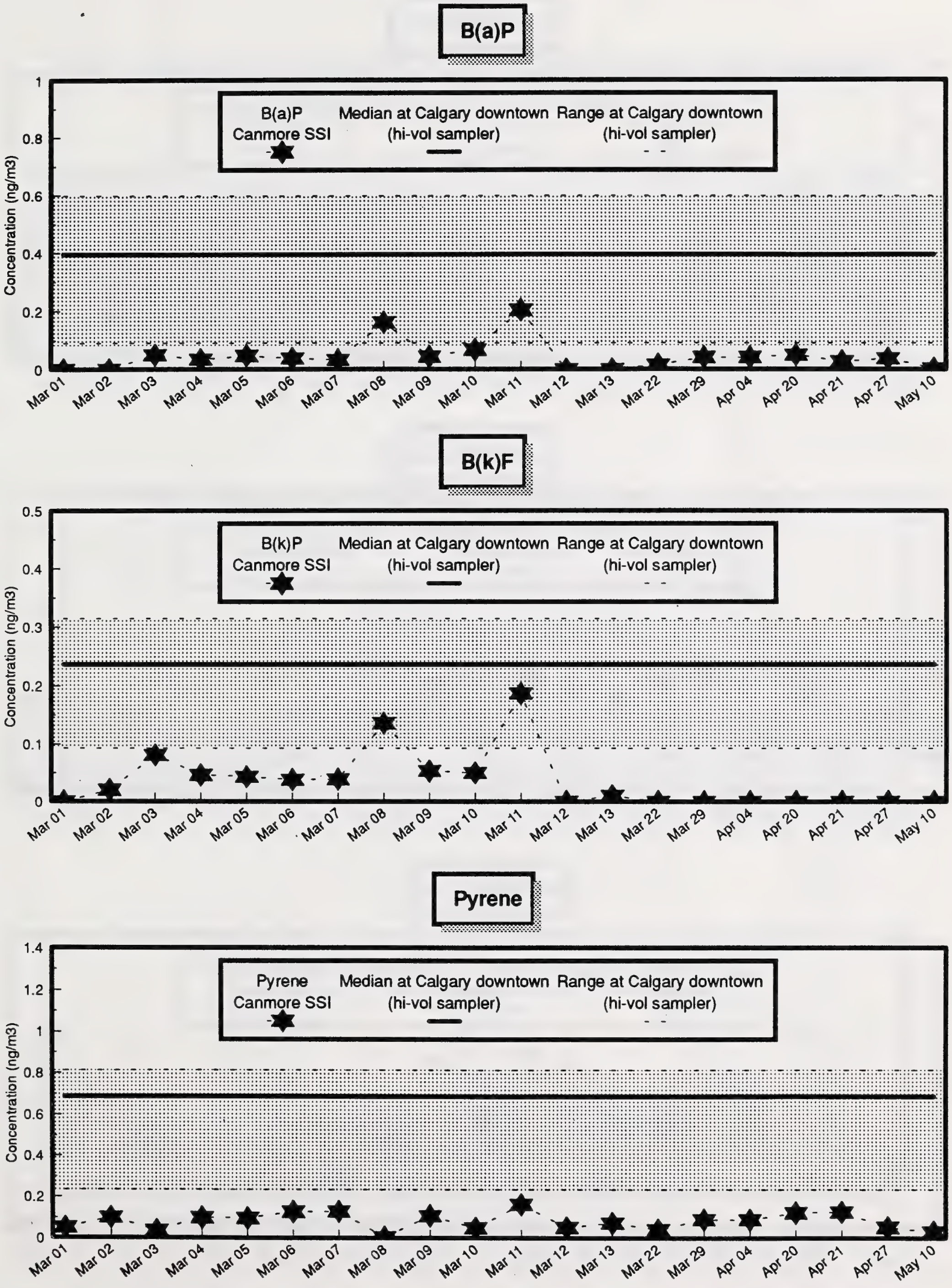


Figure 3.16 B(a)P, B(k)F and pyrene concentrations at Canmore and downtown Calgary.

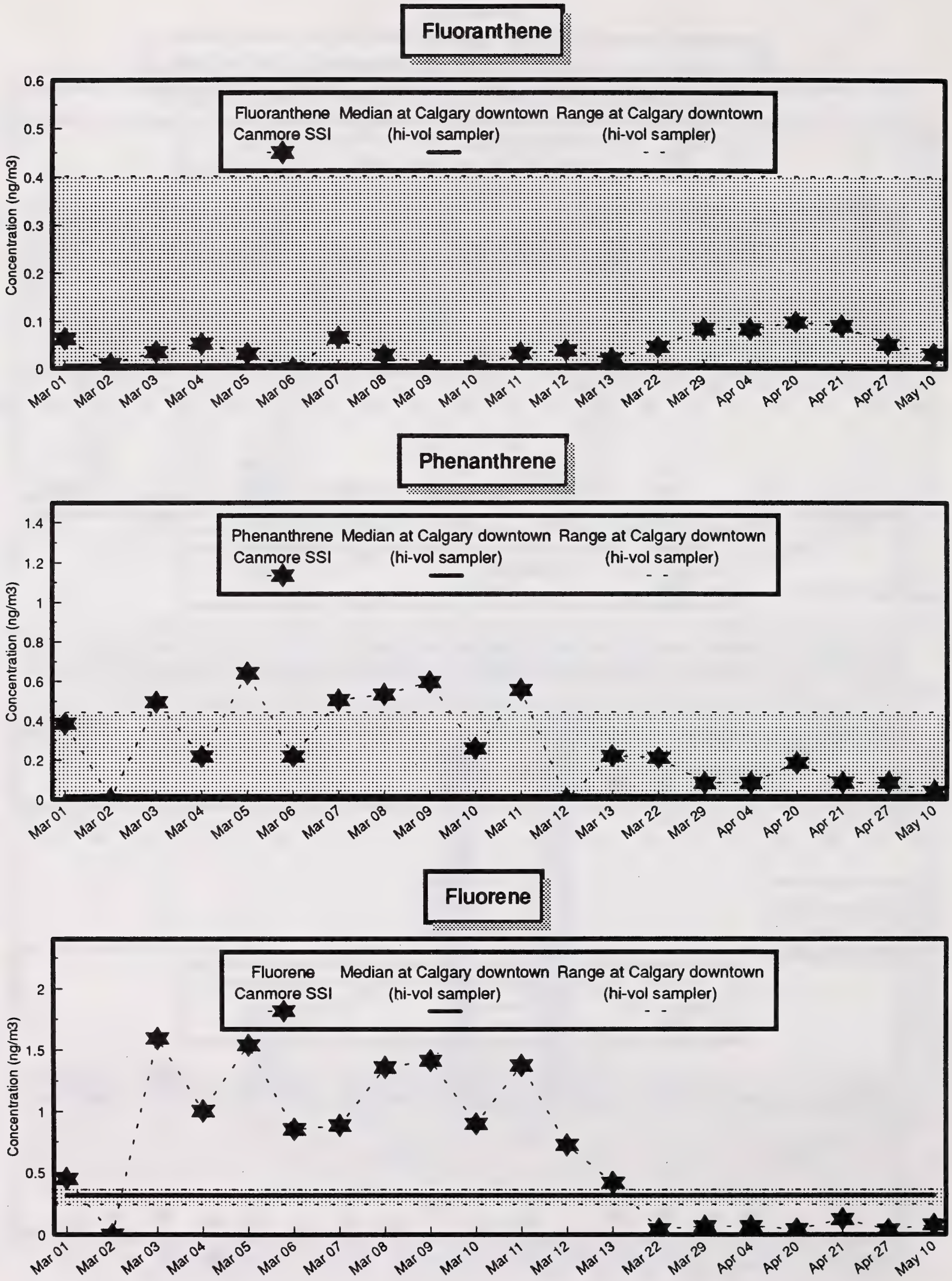
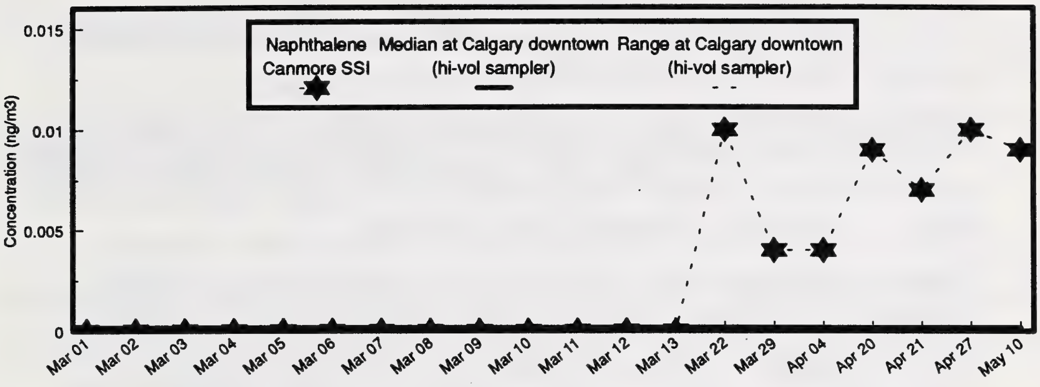
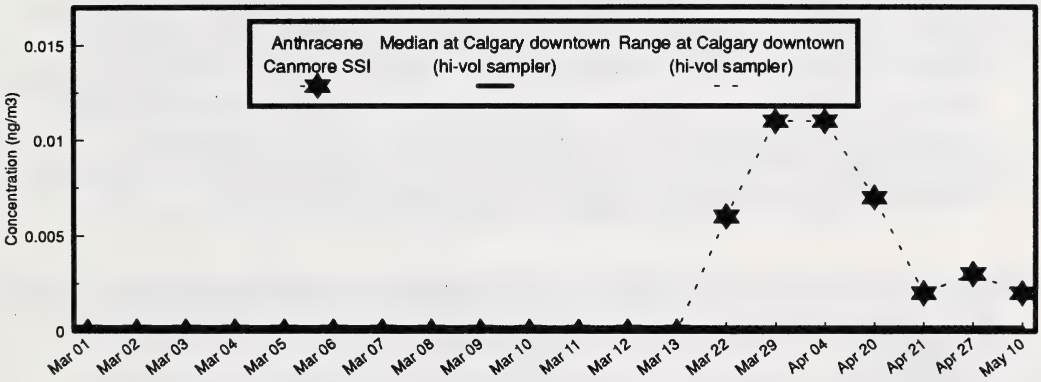


Figure 3.17 Fluoranthene, phenanthrene and fluorene concentrations at Canmore and downtown Calgary.

Naphthalene



Anthracene



Acenaphthene

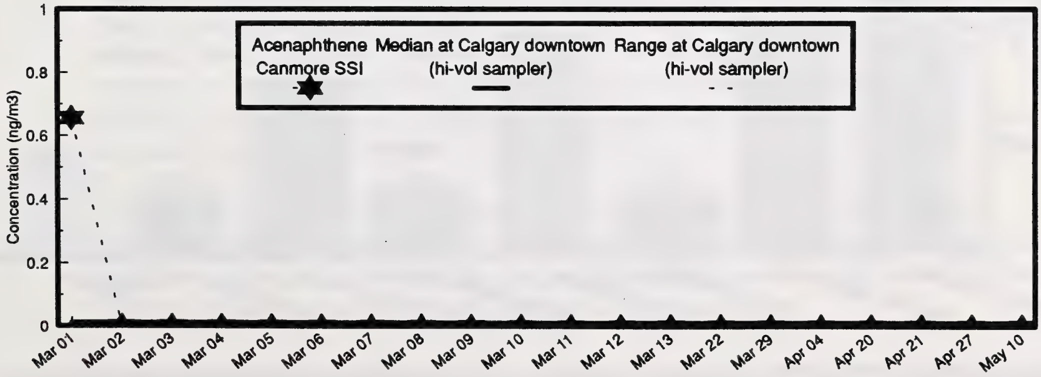


Figure 3.18 Naphthalene, anthracene and acenaphthene concentrations at Canmore and downtown Calgary.

Because of the uncertainty in the formation of PAHs, it is difficult to relate concentrations of PAHs observed in this study to definite sources. However, the following important observations can be noted from this survey:

(1) Concentrations of some PAHs (fluoranthene, phenanthrene and fluorene) were higher in Canmore SSI samples than Calgary high volume samples. Sources of fluoranthene and phenanthrene include vehicle exhaust emissions (diesel and gas vehicles) and wood smoke. A major source of fluorene is also wood smoke.

(2) Concentrations of most PAHs were either higher in *baseline* samples or almost the same in *baseline* and *test* samples. Median fluoranthene concentrations were higher in *test* samples than *baseline* samples. Naphthalene and anthracene were also detected in *test* samples, although at low concentrations. Therefore, fluoranthene, anthracene and naphthalene may originate from sources southeast of Canmore.

(3) B(a)P concentrations in Canmore were substantially lower than those recorded for the same time period in downtown Calgary. The median B(a)P value in Canmore SSI samples was about 10% of the median value in Calgary downtown high volume samples. Median B(a)P values in Canmore were close to those observed at other small urban locations (i.e. Fort Saskatchewan) in March and April (1993). Average B(a)P concentrations from provincial monitoring stations for March and April, 1993 and the median B(a)P concentration at Canmore are presented in Figure 3.19.

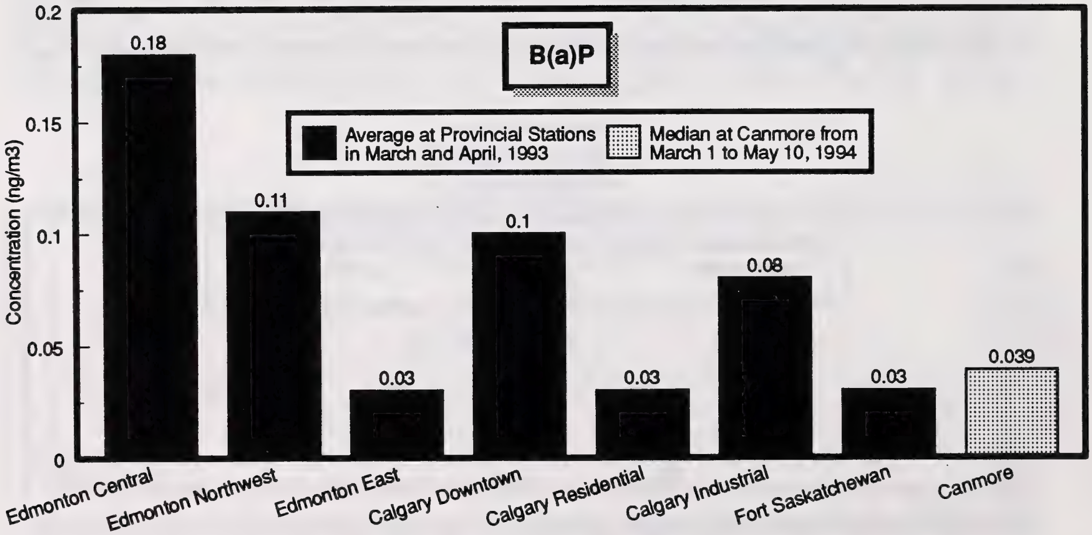


Figure 3.19 B(a)P concentrations at provincial monitoring stations (March and April, 1993) and the Canmore station (March, April and May, 1994).

4. CONCLUSIONS

An inhalable particulate study was undertaken in Canmore to address issues such as smoke from local sources, vehicular emissions and dust from industries in the Exshaw area. Based on the composition of particulates in 17 dichotomous samples and 20 SSI samples collected in Canmore, the following observations are evident:

(1) Loadings of inhalable particulates in the fine fraction in Canmore were not significantly different than those recorded over the same time in downtown Calgary. However, coarse particulate loadings in downtown Calgary were significantly higher than those measured in Canmore. The median coarse particulate loading at the Calgary downtown monitoring station was almost three times higher than median value in Canmore.

(2) Fine particulate loadings were generally higher in *baseline* samples than *test* samples. Coarse particulate loadings were higher in *test* samples. The median fine particulate loading in *test* samples was about two-thirds of that for *baseline* samples. The median coarse particulate loading in *test* samples was almost three times the median in *baseline* samples.

(3) Concentrations of sulphate, nitrate and calcium in the fine fraction were significantly higher in Canmore samples than Calgary downtown samples. In addition, ammonium concentrations in the coarse fraction were higher in Canmore samples.

(4) The median calcium concentration in the coarse fraction was over 13 times higher in *test* samples than *baseline* samples. Median concentrations of coarse sulphate, nitrate, ammonium, sodium, chloride, magnesium and potassium were at least twice as high in *test* samples as *baseline* samples. Median values of ammonium, potassium, sulphate and nitrate in the fine fraction were also higher in *test* samples.

(5) Median values of fluoranthene and phenanthrene in Canmore SSI samples were higher than those observed in high volume samples from downtown Calgary. Although, median values of these PAHs were low in both downtown Calgary and Canmore samples. It is important to emphasize that only particles less than 10 microns in diameter were collected by the Canmore SSI sampler while all particles were collected by the Calgary downtown high volume sampler.

(6) The median fluoranthene concentration was 2.7 times higher in *test* samples than *baseline* samples. Median values of naphthalene and anthracene were also higher in *test* samples (median values in *baseline* samples were below the analytical detection limit). Concentrations of other PAHs were higher in *baseline* samples.

Based on these observations, it is evident that concentrations of inhalable particles in Canmore are lower than those in downtown Calgary for most ions. Only fine sulphate, fine nitrate, fine calcium and coarse ammonium had significantly higher values in Canmore samples.

However, concentrations of many ions, especially those in the coarse fraction, were higher with more frequent winds with a southeast component. This last results implies that some of these compounds may originate southeast of Canmore, in the direction of Exshaw.

There are many natural particulate sources in the Bow Corridor. However, there are also sources such as cement manufacturing, magnesium oxide production, vehicle exhaust from highways and smoke from recreational wood burning. In downtown Calgary, vehicle exhaust is the major air pollution source. In Canmore, sulphate, nitrate, ammonium and potassium in the fine fraction likely are the result of industrial combustion processes, vehicle exhaust or wood smoke. Wind blown dust from natural sources or from industrial sources are the most probable sources of calcium, sulphate, nitrate, ammonium, sodium, chloride, magnesium and potassium in the coarse fraction. Wood smoke is also a possible source of some of these ions.

The major sources of PAHs are combustion processes. Fluoranthene, naphthalene and anthracene were the only PAHs that recorded higher median values when winds from the southeast were more frequent. Recreational wood burning and diesel exhaust emissions are the most common sources on these PAHs. Industrial processes may also contain some of these PAHs.

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APPENDIX - DICHOTOMOUS AND SSI DATA

Canmore Dichotomous Samples (fine fraction)

Sample Number	Date	Loading (ug/m3)	Chloride (ug/m3)	Nitrate (ug/m3)	Sulphate (ug/m3)	Sodium (ug/m3)
944901 F	Mar 01	7.6	0.099	0.093	0.154	0.072
944902 F	Mar 02	5.3	0.090	0.107	0.079	0.054
944903 F	Mar 03	4.5	0.063	0.086	0.084	0.043
944904 F	Mar 04	9.1	0.075	0.141	0.070	0.050
944905 F	Mar 05	21.9	0.113	0.072	0.070	0.075
944906 F	Mar 06	3.0	0.048	0.113	0.035	0.029
944907 F	Mar 07	24.2	0.107	0.099	0.154	0.059
944908 F	Mar 08	28.7	0.132	0.080	0.094	0.073
944909 F	Mar 09	41.2	0.218	0.051	0.098	0.120
944910 F	Mar 10	26.5	0.205	0.073	0.099	0.128
944911 F	Mar 11	17.0	0.111	0.131	0.236	0.063
944912 F	Mar 12	1.9	0.023	0.036	0.025	0.013
944913F	Mar 13	11.0	0.089	0.104	0.174	0.091
944917F	Apr 20	5.4	0.201	0.205	0.618	0.152
944918F	Apr 21	11.3	0.108	0.162	0.146	0.071
944919F	Apr 27	9.1	0.076	0.088	0.133	0.047
944920F	May 10	5.1	0.088	0.069	0.123	0.045

Sample Number	Date	Ammonium (ug/m3)	Potassium (ug/m3)	Magnesium (ug/m3)	Calcium (ug/m3)
944901 F	Mar 01	0.010	0.010	0.041	0.685
944902 F	Mar 02	0.015	0.017	0.053	0.747
944903 F	Mar 03	0.010	0.008	0.031	0.466
944904 F	Mar 04	0.017	0.010	0.089	1.867
944905 F	Mar 05	0.008	0.011	0.042	4.043
944906 F	Mar 06	0.008	0.011	0.010	0.255
944907 F	Mar 07	0.020	0.010	0.073	5.037
944908 F	Mar 08	0.008	0.011	0.051	5.446
944909 F	Mar 09	0.008	0.013	0.062	6.928
944910 F	Mar 10	0.009	0.013	0.051	5.740
944911 F	Mar 11	0.036	0.017	0.117	3.270
944912 F	Mar 12	0.002	0.005	0.012	0.284
944913F	Mar 13	0.020	0.020	0.027	0.351
944917F	Apr 20	0.038	0.361	0.050	2.619
944918F	Apr 21	0.031	0.028	0.034	0.407
944919F	Apr 27	0.028	0.014	0.035	0.417
944920F	May 10	0.020	0.019	0.034	0.504

Canmore Dichotomous Samples (coarse fraction)

Sample Number	Date	Loading (ug/m3)	Chloride (ug/m3)	Nitrate (ug/m3)	Sulphate (ug/m3)	Sodium (ug/m3)
944901 C	Mar 01	5.3	0.057	0.067	0.175	0.032
944902 C	Mar 02	4.2	0.160	0.073	0.241	0.265
944903 C	Mar 03	4.5	0.027	0.050	0.129	0.024
944904 C	Mar 04	3.0	0.058	0.110	0.188	0.049
944905 C	Mar 05	4.9	0.056	0.037	0.225	0.042
944906 C	Mar 06	2.3	0.043	0.125	0.045	0.036
944907 C	Mar 07	5.3	0.037	0.177	0.565	0.030
944908 C	Mar 08	5.7	0.047	0.035	0.228	0.027
944909 C	Mar 09	8.3	0.042	0.047	0.243	0.033
944910 C	Mar 10	6.8	0.043	0.065	0.226	0.038
944911 C	Mar 11	7.6	0.026	0.198	0.950	0.031
944912 C	Mar 12	1.1	0.026	0.022	0.033	0.015
944913C	Mar 13	9.1	0.057	0.051	0.076	0.045
944917C	Apr 20	18.1	0.110	0.246	0.671	0.106
944918C	Apr 21	16.8	0.115	0.185	0.405	0.087
944919C	Apr 27	14.7	0.063	0.256	2.427	0.060
944920C	May 10	17.1	0.076	0.235	0.683	0.100

Sample Number	Date	Ammonium (ug/m3)	Potassium (ug/m3)	Magnesium (ug/m3)	Calcium (ug/m3)
944901 C	Mar 01	0.048	0.011	0.011	0.113
944902 C	Mar 02	0.063	0.091	0.026	0.186
944903 C	Mar 03	0.045	0.011	0.009	0.096
944904 C	Mar 04	0.071	0.021	0.021	0.217
944905 C	Mar 05	0.066	0.011	0.032	0.337
944906 C	Mar 06	0.007	0.011	0.010	0.129
944907 C	Mar 07	0.178	0.023	0.042	0.498
944908 C	Mar 08	0.063	0.008	0.040	0.610
944909 C	Mar 09	0.063	0.011	0.048	1.102
944910 C	Mar 10	0.064	0.016	0.039	0.581
944911 C	Mar 11	0.307	0.057	0.036	0.379
944912 C	Mar 12	0.001	0.005	0.014	0.193
944913C	Mar 13	0.028	0.014	0.020	0.260
944917C	Apr 20	0.165	0.043	0.080	4.595
944918C	Apr 21	0.119	0.034	0.080	3.894
944919C	Apr 27	0.714	0.045	0.071	2.572
944920C	May 10	0.184	0.032	0.085	3.079

Calgary Dichotomous Samples (fine fraction)

Sample Number	Date	Loading (ug/m3)	Chloride (ug/m3)	Nitrate (ug/m3)	Sulphate (ug/m3)	Sodium (ug/m3)
D5669F	Mar 03	7	0.231	0.235	0.301	0.204
D5671F	Mar 09	9	0.079	0.473	0.504	0.172
D5673F	Mar 15	11	nd	0.335	0.796	0.085
D5675F	Mar 21	9	0.026	0.265	1.328	0.078
D5677F	Mar 27	5	0.017	0.178	0.715	0.055
D5679F	Apr 02	10	no data	no data	no data	no data
D5681F	Apr 08	19	no data	no data	no data	no data
D5683F	Apr 14	5	no data	no data	no data	no data

Sample Number	Date	Ammonium (ug/m3)	Potassium (ug/m3)	Magnesium (ug/m3)	Calcium (ug/m3)
D5669F	Mar 03	0.052	0.049	0.030	0.358
D5671F	Mar 09	0.142	0.090	0.038	0.340
D5673F	Mar 15	0.291	0.072	0.037	0.276
D5675F	Mar 21	0.594	nd	0.036	0.180
D5677F	Mar 27	0.242	0.038	0.038	0.152
D5679F	Apr 02	no data	no data	no data	no data
D5681F	Apr 08	no data	no data	no data	no data
D5683F	Apr 14	no data	no data	no data	no data

nd - not detected in sample

Calgary Dichotomous Samples (coarse fraction)

Sample Number	Date	Loading (ug/m3)	Chloride (ug/m3)	Nitrate (ug/m3)	Sulphate (ug/m3)	Sodium (ug/m3)
D5668C	Mar 03	44	3.670	0.150	0.428	2.428
D5670C	Mar 09	45	2.814	0.193	0.261	1.911
D5672C	Mar 15	34	0.746	0.236	0.499	0.548
D5674C	Mar 21	18	0.377	0.136	0.236	0.262
D5676C	Mar 27	15	0.381	0.187	0.156	0.301
D5678C	Apr 02	12	no data	no data	no data	no data
D5680C	Apr 08	11	no data	no data	no data	no data
D5682C	Apr 14	6	no data	no data	no data	no data

Sample Number	Date	Ammonium (ug/m3)	Potassium (ug/m3)	Magnesium (ug/m3)	Calcium (ug/m3)
D5668C	Mar 03	nd	0.050	0.103	3.970
D5670C	Mar 09	nd	0.041	0.116	3.880
D5672C	Mar 15	0.013	0.034	0.114	3.290
D5674C	Mar 21	nd	0.013	0.087	1.830
D5676C	Mar 27	0.008	0.013	0.070	1.300
D5678C	Apr 02	no data	no data	no data	no data
D5680C	Apr 08	no data	no data	no data	no data
D5682C	Apr 14	no data	no data	no data	no data

Canmore SSI Samples

Sample Number	Date	Loading (ug/m3)	Anthracene (ng/m3)	Naphthalene (ng/m3)	Fluorene (ng/m3)	Phenanthrene (ng/m3)
19001	Mar 01	4	<nd	<nd	0.450	0.385
20001	Mar 02	11	<nd	<nd	nd	nd
19002	Mar 03	6	<nd	<nd	1.591	0.495
20002	Mar 04	17	<nd	<nd	1.000	0.217
19003	Mar 05	38	<nd	<nd	1.536	0.640
20003	Mar 06	50	<nd	<nd	0.850	0.217
19004	Mar 07	59	<nd	<nd	0.883	0.504
20004	Mar 08	99	<nd	<nd	1.356	0.533
19005	Mar 09	46	<nd	<nd	1.410	0.596
20005	Mar 10	42	<nd	<nd	0.896	0.258
19006	Mar 11	52	<nd	<nd	1.373	0.556
20006	Mar 12	54	<nd	<nd	0.722	nd
19007	Mar 13	13	<nd	<nd	0.417	0.220
19008	Mar 22	23	0.006	0.010	0.044	0.210
20008	Mar 29	35	0.011	0.004	0.069	0.082
20008	Apr 04	35	0.011	0.004	0.069	0.082
19009	Apr 20	31	0.007	0.009	0.043	0.183
20009	Apr 21	26	0.002	0.007	0.126	0.083
19010	Apr 27	22	0.003	0.010	0.040	0.084
20010	May 10	17	0.002	0.009	0.080	0.038

Sample Number	Date	Acenaphthene (ng/m3)	B(k)F (ng/m3)	Fluoranthene (ng/m3)	B(a)P (ng/m3)	Pyrene (ng/m3)
19001	Mar 01	0.655	nd	0.063	<nd	0.050
20001	Mar 02	<nd	0.020	0.010	<nd	0.099
19002	Mar 03	<nd	0.081	0.035	0.051	0.036
20002	Mar 04	<nd	0.046	0.052	0.035	0.098
19003	Mar 05	<nd	0.043	0.031	0.048	0.096
20003	Mar 06	<nd	0.038	<nd	0.039	0.127
19004	Mar 07	<nd	0.039	0.065	0.034	0.128
20004	Mar 08	<nd	0.136	0.028	0.163	0.005
19005	Mar 09	<nd	0.053	0.006	0.045	0.107
20005	Mar 10	<nd	0.050	0.004	0.069	0.048
19006	Mar 11	<nd	0.187	0.032	0.205	0.162
20006	Mar 12	<nd	nd	0.038	<nd	0.051
19007	Mar 13	<nd	0.010	0.020	<nd	0.072
19008	Mar 22	<nd	<nd	0.045	0.017	0.041
20008	Mar 29	<nd	<nd	0.083	0.043	0.089
20008	Apr 04	<nd	<nd	0.083	0.043	0.089
19009	Apr 20	<nd	<nd	0.098	0.051	0.122
20009	Apr 21	<nd	<nd	0.090	0.029	0.126
19010	Apr 27	<nd	<nd	0.051	0.039	0.052
20010	May 10	<nd	<nd	0.031	0.004	0.030

<nd - chemical was not detected

Calgary downtown High Volume Samples

Sample Number	Date	Loading (ug/m3)	Anthracene (ng/m3)	Naphthalene (ng/m3)	Fluorene (ng/m3)	Phenanthrene (ng/m3)
2D 437	Mar 03	134	<nd	<nd	0.363	0.445
2D 438	Mar 09	103	<nd	<nd	0.327	<nd
2D 439	Mar 15	98	<nd	<nd	0.338	<nd
2D 440	Mar 21	58	<nd	<nd	0.316	<nd
2D 441	Mar 27	47	<nd	<nd	0.302	<nd
2D 442	Apr 02	47	<nd	<nd	0.245	<nd
2D 443	Apr 08	44	<nd	<nd	0.251	<nd

Sample Number	Date	Acenaphthene (ng/m3)	B(k)F (ng/m3)	Fluoranthene (ng/m3)	B(a)P (ng/m3)	Pyrene (ng/m3)
2D 437	Mar 03	<nd	0.303	0.402	0.597	0.815
2D 438	Mar 09	<nd	0.236	<nd	0.435	0.724
2D 439	Mar 15	<nd	0.315	0.313	0.599	0.684
2D 440	Mar 21	<nd	0.270	<nd	0.396	0.750
2D 441	Mar 27	<nd	0.142	<nd	0.193	0.335
2D 442	Apr 02	<nd	0.093	<nd	0.092	0.234
2D 443	Apr 08	<nd	0.176	<nd	0.241	0.441

<nd - chemical was not detected

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